Keeyask Generation Project

Terrestrial Effects Monitoring Plan

Olive-sided Flycatcher and Rusty Blackbird Monitoring Report

TEMP-2021-13

Manitoba Conservation and Climate Client File 5550.00
Manitoba Environment Act Licence No. 3107

2020 - 2021

KEEYASK GENERATION PROJECT

TERRESTRIAL EFFECTS MONITORING PLAN

REPORT #TEMP-2021-13

OLIVE-SIDED FLYCATCHER AND RUSTY BLACKBIRD SENSORY DISTURBANCE MONITORING

Prepared for

Manitoba Hydro

By

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June 2021

This report should be cited as follows:

ECOSTEM Ltd. and Wildlife Resource Consulting Services MB Inc. 2021. Keeyask Generation Project Terrestrial Effects Monitoring Plan Report #TEMP-2021-13: Olive-sided Flycatcher and Rusty Blackbird Sensory Disturbance Monitoring. A report prepared for Manitoba Hydro by ECOSTEM Ltd. and Wildlife Resource Consulting Services MB Inc., June 2021.

SUMMARY

Background

Construction of the Keeyask Generation Project (the Project) at Gull Rapids began in July 2014. The Keeyask Hydropower Limited Partnership (KHLP) was required to prepare a plan to monitor the effects of construction and operation of the generating station on the terrestrial environment. Monitoring results will help the KHLP, government regulators, members of local First Nation communities, and the general public understand how construction and operation of the generating station will affect the environment, and whether more needs to be done to reduce harmful effects.

Olive-sided flycatcher and rusty blackbird are migratory songbirds that are found in the Keeyask region. Both species are considered species at risk in Canada and are protected under the federal *Species at Risk Act*. In Manitoba, the olive-sided flycatcher is also listed as Threatened under *The Endangered Species and Ecosystems Act*.

Why is the study being done?

Both the olive-sided flycatcher and rusty blackbird are near the edge of their breeding ranges in northern Manitoba and are found in relatively low numbers in the Keeyask region. Both are species at risk, have been experiencing widespread declines throughout their ranges, and may be vulnerable to Project effects. The goal of this study was to monitor the effect of Project-related disturbance on these species near the North and South access roads, the areas where Project disturbance was expected to be greatest.

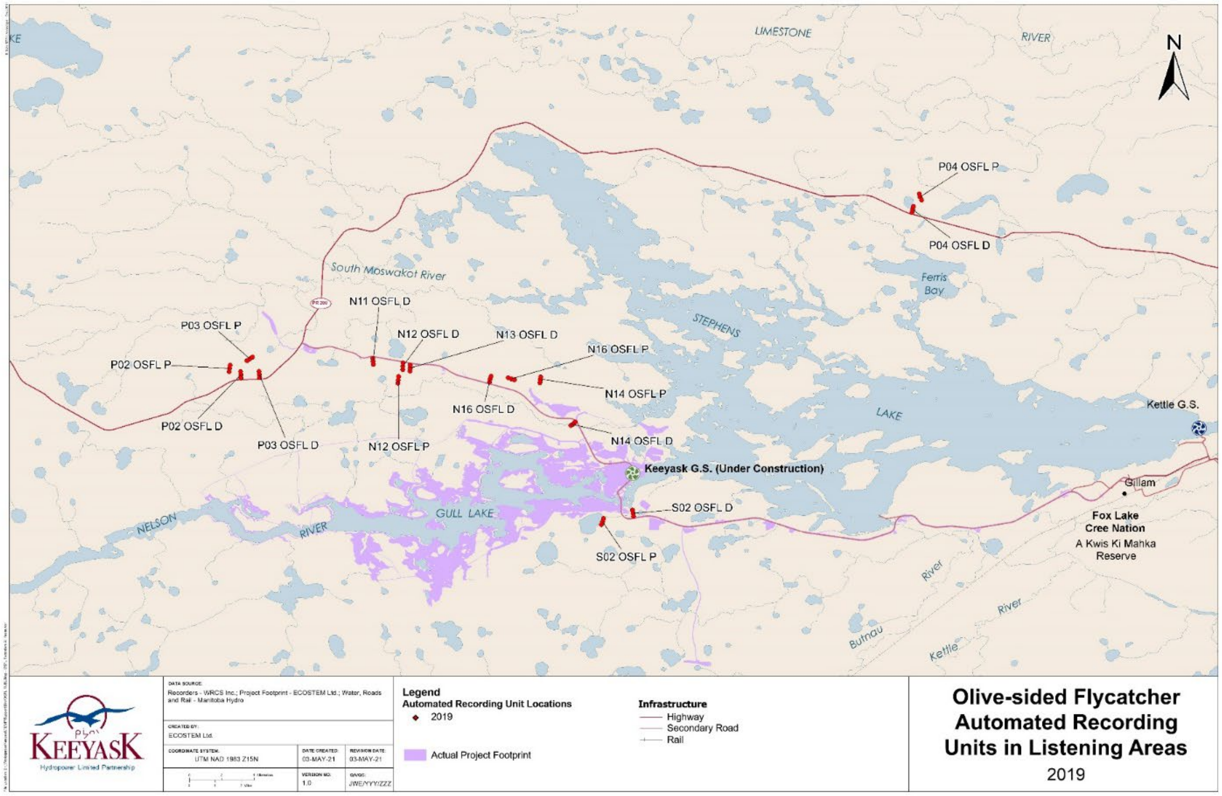
Rusty blackbird

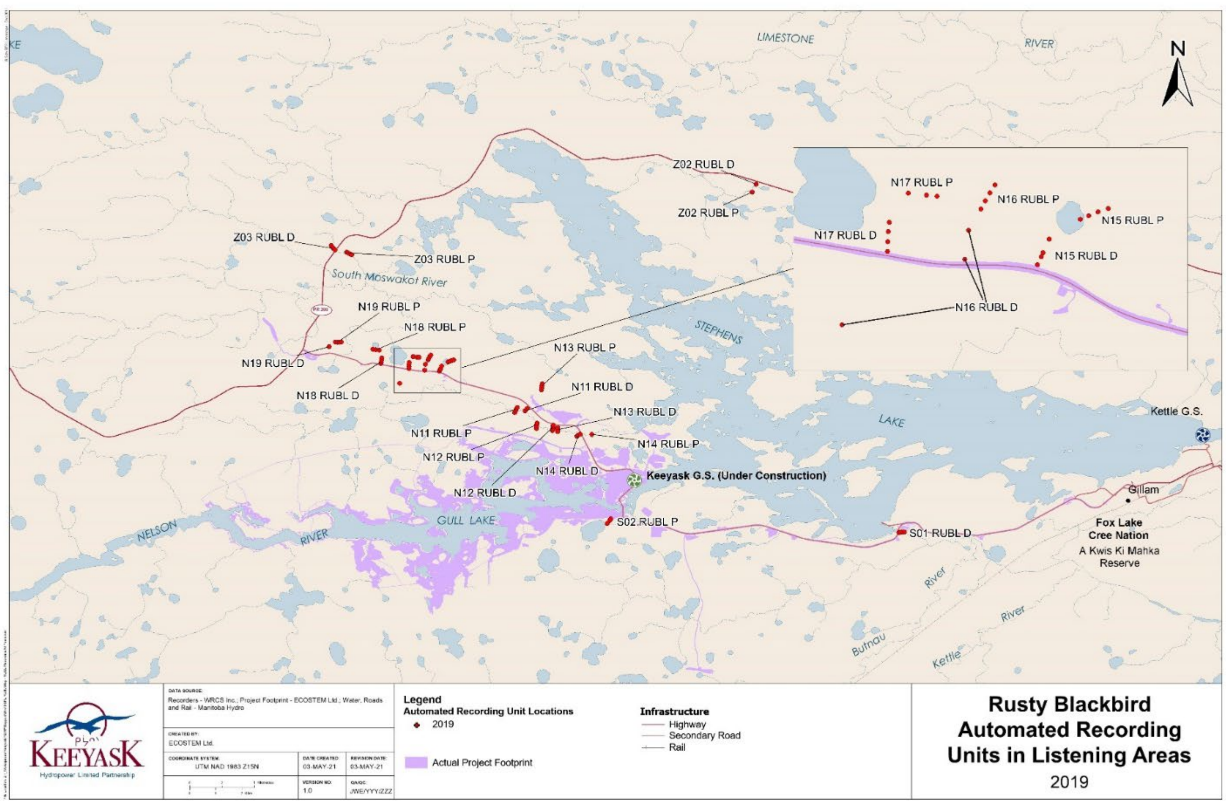
What was done?

Potential olive-sided flycatcher and rusty blackbird nesting territories were mapped near the North Access Road and South Access Road, which are Project-related sources of disturbance. Automated recording units, designed to record bird calls, were placed within the mapped territories in mid-June to early July of 2016, 2017 and 2019. Nesting territories near Provincial Road 280, an existing source of disturbance, were also included for comparison. For each potential nesting territory surveyed at a disturbed site, a potential nesting territory at a site with no disturbance was also surveyed.

Recordings from automated recording units were analyzed and olive-sided flycatcher and rusty blackbird calls were identified and counted. The number of calls for each location within the recorder listening area was calculated, and maps were produced showing areas with high and low olive-sided flycatcher or rusty blackbird activity.

Biologist setting up an automated recording unit to record bird calls





Example maps of olive-sided flycatcher and rusty blackbird ARU locations

What was found?

The extremely large amount of olive-sided flycatcher and rusty blackbird abundance and location data (around 408,000 calls) were processed and explored for potential recorder issues (e.g., battery failure, duplicate or missing data) and other factors such as limitations on the estimated distance and direction from the record.

There was considerable variation in the amount of olive-sided flycatcher and rusty blackbird activity in each area mapped as a territory. The number of calls was high in some disturbed and undisturbed areas and was low in others. While olive-sided flycatchers sang most often near sunrise, no pattern of activity for rusty blackbirds was identified.

What does it mean?

Areas with high numbers of calls likely contained preferred perching locations and suitable breeding habitat. Areas with few or no calls may have been affected by sensory disturbance or are in poor-quality habitat; birds may have been perching temporarily while searching for a territory; or birds may have relocated partway through the breeding season. Although there was no obvious indication that sensory disturbance from the access roads reduced habitat effectiveness by causing olive-sided flycatchers or rusty blackbirds to avoid it, some areas showed low or no activity near the access roads. Low activity could indicate poor quality habitat, sensory disturbance or the confounding effect of other factors (e.g., higher or lower vegetation density affecting the estimated distance to calls).

What will be done next?

To determine whether the access roads are affecting olive-sided flycatcher and rusty blackbird habitat use, additional habitat mapping as well as statistical and GIS analyses will be completed. This will focus on separating the bird response to sensory disturbance from other factors such as differences in habitat, vegetation density and amount of sensory disturbance.

STUDY TEAM

We would like to thank Sherrie Mason and Rachel Boone of Manitoba Hydro and Ron Bretecher of North/South Consultants Inc. for logistical assistance in the field. Biologists and other personnel who designed, participated in, and drafted the survey results included:

- Dr. James Ehnes, ECOSTEM Ltd. – Design, data analysis and reporting
- Brock Epp, ECOSTEM Ltd. – Data analysis and reporting
- Robert Berger, Wildlife Resource Consulting Services MB Inc. – Design and reporting
- Alex McIlraith, Independent - Design and bird audio recording analysis

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS

LIST OF PHOTOS

LIST OF APPENDICES

1.0 INTRODUCTION

Construction of the Keeyask Generation Project (the Project), a 695-megawatt hydroelectric generating station (GS) and associated facilities, began in July 2014. The Project is located at Gull Rapids on the lower Nelson River in northern Manitoba where Gull Lake flows into Stephens Lake, 35 km upstream of the existing Kettle GS.

The *Keeyask Generation Project Response to EIS Guidelines* (the EIS), completed in June 2012, provides a summary of predicted effects and planned mitigation for the Project. Technical supporting information for the terrestrial environment, including a description of the environmental setting, effects and mitigation, and a summary of proposed monitoring and follow-up programs is provided in the *Keeyask Generation Project Environmental Impact Statement Terrestrial Supporting Volume* (TE SV). The *Keeyask Generation Project Terrestrial Effects Monitoring Plan* (TEMP) was developed as part of the licensing process for the Project. Monitoring activities for various components of the terrestrial environment were described, including the focus of this report, olive-sided flycatcher (*Contopis cooperi*) and rusty blackbird (*Euphagus carolinus*), during Project construction.

Olive-sided flycatcher (Photo 1-1) and rusty blackbird (Photo 1-2) are migratory songbirds protected under the federal *Species at Risk Act* (SARA). The olive-sided flycatcher is listed as Threatened under the SARA and is listed as Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). In Manitoba, the olive-sided flycatcher is listed as Threatened under *The Endangered Species and Ecosystems Act*. Its breeding habitat consists mainly of mature coniferous forest with open patches created by natural disturbance (e.g., fire), wetlands, or forestry clear-cuts (Altman and Sallabanks 2012 in Environment Canada 2016). Snags (dead standing trees) and live trees left behind after logging are important for perching while foraging for flying insects in open areas (Altman and Sallabanks 2012 in Environment Canada 2016).

The rusty blackbird is listed as Special Concern under the SARA and has no designation under *The Endangered Species and Ecosystems Act* of Manitoba. Despite being a migratory bird, the rusty blackbird is not protected under the federal *Migratory Birds Convention Act 1994*. Rusty blackbirds inhabit the boreal forest during the breeding season, using wetland habitat such as sedge meadows, beaver ponds, muskegs, swamps, riparian scrub, and shrubby patches of willow and alder (COSEWIC 2017). Their diet consists mainly of aquatic invertebrates such as insect larvae and snails, and also grasshoppers, beetles, and spiders (COSEWIC 2017).

As part of the TEMP, pilot studies for olive-sided flycatcher and rusty blackbird were conducted in 2015, to identify and enumerate breeding pairs of birds in the Keeyask region. Sensory disturbance surveys were then conducted in 2016, 2017, and 2019, to determine if and how Project-related noise affects the distribution and abundance of each species. The Project's north and south access roads were expected to be the main sources of sensory disturbance for olive-sided flycatcher and rusty blackbird.

Photo 1-1: Olive-sided flycatcher

Photo 1-2: Rusty blackbird

2.0 METHODS

2.1 FIELD STUDIES

2.1.1 PILOT STUDY

The goal of the 2015 pilot study was to determine if enough olive-sided flycatchers and rusty blackbirds were in the study area to support a credible study design (WRCS 2020). Survey points were located throughout Study Zone 4 (Map 2-1) to locate territories of breeding olive-sided flycatchers and rusty blackbirds. Four types of points were surveyed in 2015 (Table 2-1):

- Habitat association points - located every 50 m on 600 m-long transects that were placed in locations thought to be high or intermediate-quality olive-sided flycatcher or rusty blackbird habitat throughout Study Zone 4. These points were established to provide information on habitat use in the Keeyask region for the expert information model to be developed following construction monitoring.
- Field points - located every 100 m on transects that were 600 m long near major roads, or 300 m long near the Project footprint.
- Systematic points - roadside stop survey with points located every 300 m along Provincial Road (PR) 280, the North Access Road (NAR), and South Access Road (SAR).
- Sample habitat association points - located every 50 m on 600 m transects that were placed in olive-sided flycatcher and rusty blackbird habitat. These points were established to provide information on habitat use in the Keeyask region for the habitat quality model to be developed following construction monitoring.

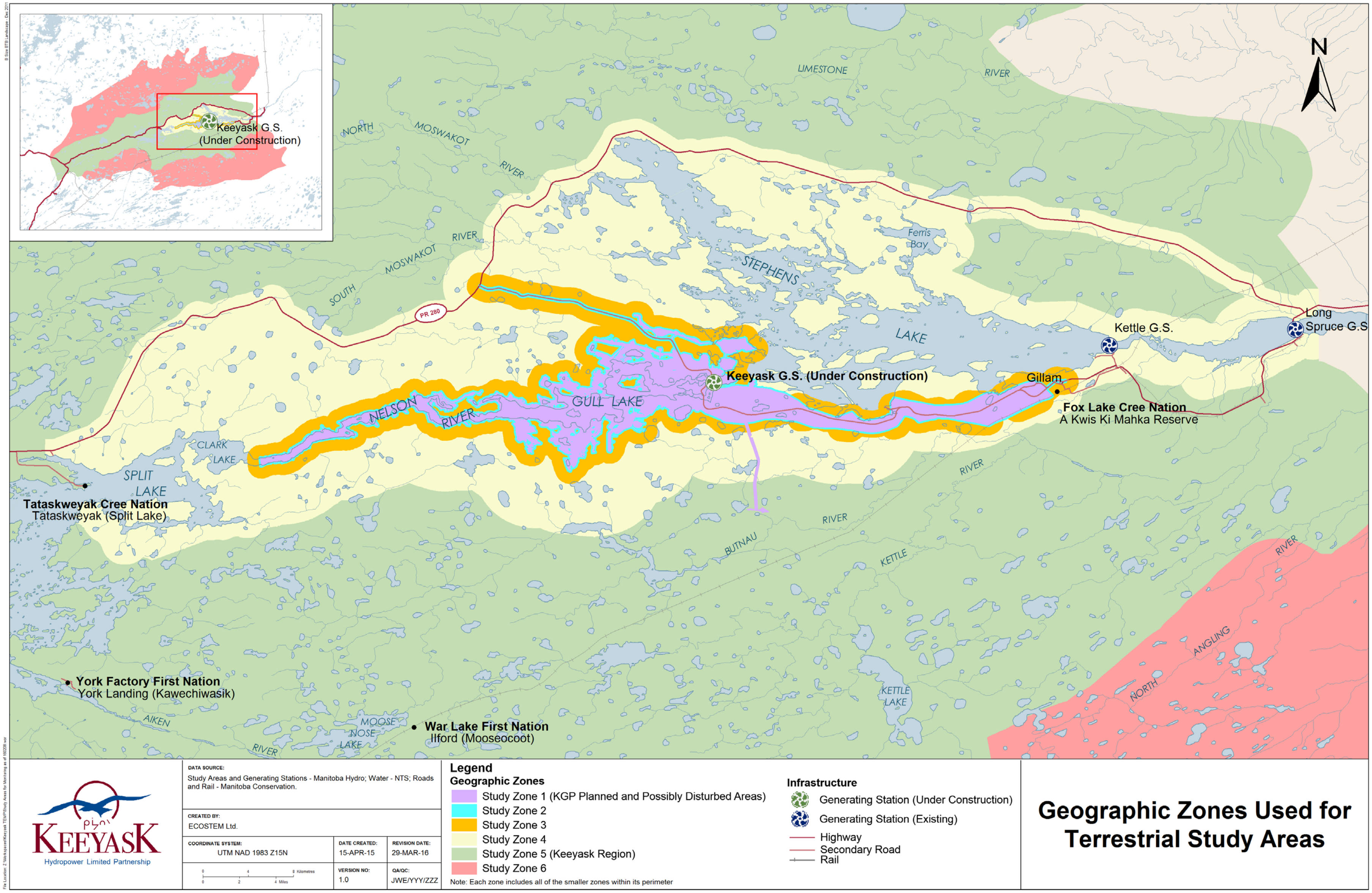
Table 2-1: Point types surveyed for olive-sided flycatcher and rusty blackbird in 2015

Survey Point Type	Number Surveyed
Habitat association	25
Olive-sided flycatcher field	110
Rusty blackbird field	63
Systematic	106
Sample habitat association	55
Total	359

Surveys were conducted in June and July 2015. Surveys began a half-hour before sunrise and concluded no later than 10 AM. At each survey point, observers watched and listened for olive-sided flycatchers and rusty blackbirds for a period of 10 minutes (Photo 2-1). If no bird was heard or observed the observer travelled to the next survey point and repeated the process. When an olive-sided flycatcher or rusty blackbird was heard or observed at one of these locations, observers marked its position using a Global Positioning System (GPS) unit. The bird was observed until three perches were marked. This was defined as the bird's territory in 2015. Territory sizes were not estimated as only three perch locations were collected. Observers maintained a sufficient distance from the bird to avoid disturbance and record natural perch locations.

Recorders (Tascam DR100-MKII) and first-generation automated recording units (ARUs) were used to verify the observations (Photo 2-1). Both datasets were used to test the quality and capabilities of the second-generation ARUs.

Photo 2-1: Technician conducting a bird survey



Map 2-1: Study zones used for the terrestrial monitoring.

2.1.2 TERRITORY MAPPING AND AUDIO RECORDING

Potential olive-sided flycatcher (OSFL) and rusty blackbird (RUBL) nesting territories identified during the 2015 pilot survey were revisited in 2016. Surveys were conducted in 2017 and 2019, where territories identified the previous year were revisited, and where new territories were found for OSFL (Table 2-2) and RUBL (Table 2-3). A paired habitat sample design was employed to follow the TEMP. Survey sites represented either Project-disturbed or reference sites. Project-disturbed sites (disturbed sites) were within 500 m of the NAR and SAR. PR 280 was also included to compare an existing source of sensory disturbance with Project-related sensory disturbance. For each disturbed site, a reference (undisturbed) site, located in similar habitat but beyond the expected range of sensory disturbance for OSFL and RUBL (500 m) was also surveyed.

In each sample year, surveys were conducted from late May to early July, began half an hour before sunrise, and concluded no later than 10 AM. At each survey site, observers watched and listened for OSFL and RUBL for a period of 10 minutes. If no bird was heard or observed, the observer repeated the process at the next site. When a bird was heard or observed at a site, observers marked its position using a GPS unit. The bird was observed until at least five perches were marked, defining its territory. Observers maintained a sufficient distance from the bird to avoid disturbance and record natural perch locations.

Two to four second-generation ARUs (Photo 2-2) were placed in or near potential territories at disturbed sites, at distances of 100 m, 300 m, 500 m, and 700 m from the nearest road (Figure 2-1). Three or four ARUs were placed in or near each territory at reference sites, at 100 m, 300 m, 500 m, and 700 m from a non-habitat patch edge such that they were centrally located through the long side of the habitat patch (Map 2-2 to Map 2-7 – Note: Labels identify unique listening areas (i.e. a potential nesting territory). Letters at the end of the label identify “Project-disturbed” sites (“D”), or reference sites (“P” or “B”)). See Wildlife Resource Consulting Services MB Inc. (WRCS 2018, 2020) for detailed field methods.

The ARUs were programmed to record for 5 minutes at 10-minute intervals (i.e., six times per hour) for seven hours beginning half an hour before sunrise and for four hours beginning an hour before sunset. Audio recording units were typically left in place for 10 days (the set period). The target listening period for OSFL and RUBL was the seven hours beginning half an hour before sunrise. The remaining four-hour listening period was recorded for other species of interest. The minimum set period was seven days for one territory in 2017, and the maximum was 20 days for one territory in 2016. Sixty-six recordings were made daily at each potential territory over the duration of the survey period, and 42 recordings were made during the target listening period.

The total number of potential territories and the number of ARUs located in them varied across the three survey years. For OSFL, in 2016, a total of 131 ARUs were located in 38 potential territories (Table 2-2; Map 2-2). A total of 87 and 89 ARUs were located in 2017 and 2019, respectively, for 29 potential territories in each year (Map 2-3 and Map 2-4). The number of ARUs per territory ranged from two to seven in 2016, and from two to four in 2017 and 2019.

For RUBL, a total of 98 ARUs were set in 37 potential territories in 2016 (Table 2-3; Map 2-5). In 2017, a total of 172 ARUs were set in 42 potential territories (Map 2-6), and in 2019 a total of 123 ARUs were set in 38 potential territories (Map 2-7).

Table 2-2: Automated recording unit sites surveyed for olive-sided flycatcher in 2016, 2017 and 2019

Sensory Disturbance	2016	2017	2019
North Access Road	34	22	16
Undisturbed	33	22	10
South Access Road	3	-	3
Undisturbed	7	-	3
PR 280	27	14	9
Undisturbed	14	5	9
CP Transmission Line [1]	7	12	18
Undisturbed	6	12	21
Total	**131**	**87**	**89**

Table 2-3: Automated recording unit sites surveyed for rusty blackbird in 2016, 2017 and 2019

Sensory Disturbance	2016	2017	2019
North Access Road	18	48	28
Undisturbed	17	47	31
South Access Road	3	12	4
Undisturbed	6	12	3
PR 280	12	14	5
Undisturbed	14	7	5
CP Transmission Line [2]	15	22	25
Undisturbed	13	10	22
Total	**98**	**172**	**123**

Notes: [1, 2] Further analyses of olive-sided flycatcher and rusty blackbird associated with transmission lines will be addressed in a separate report.

Photo 2-2: Four-microphone automated recording unit housed in protective case

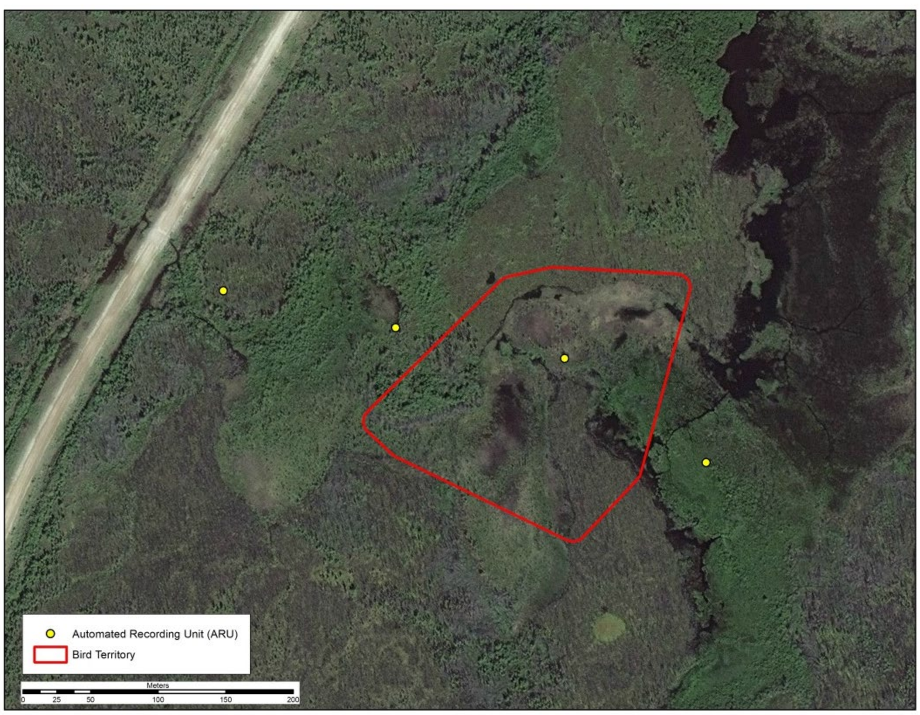
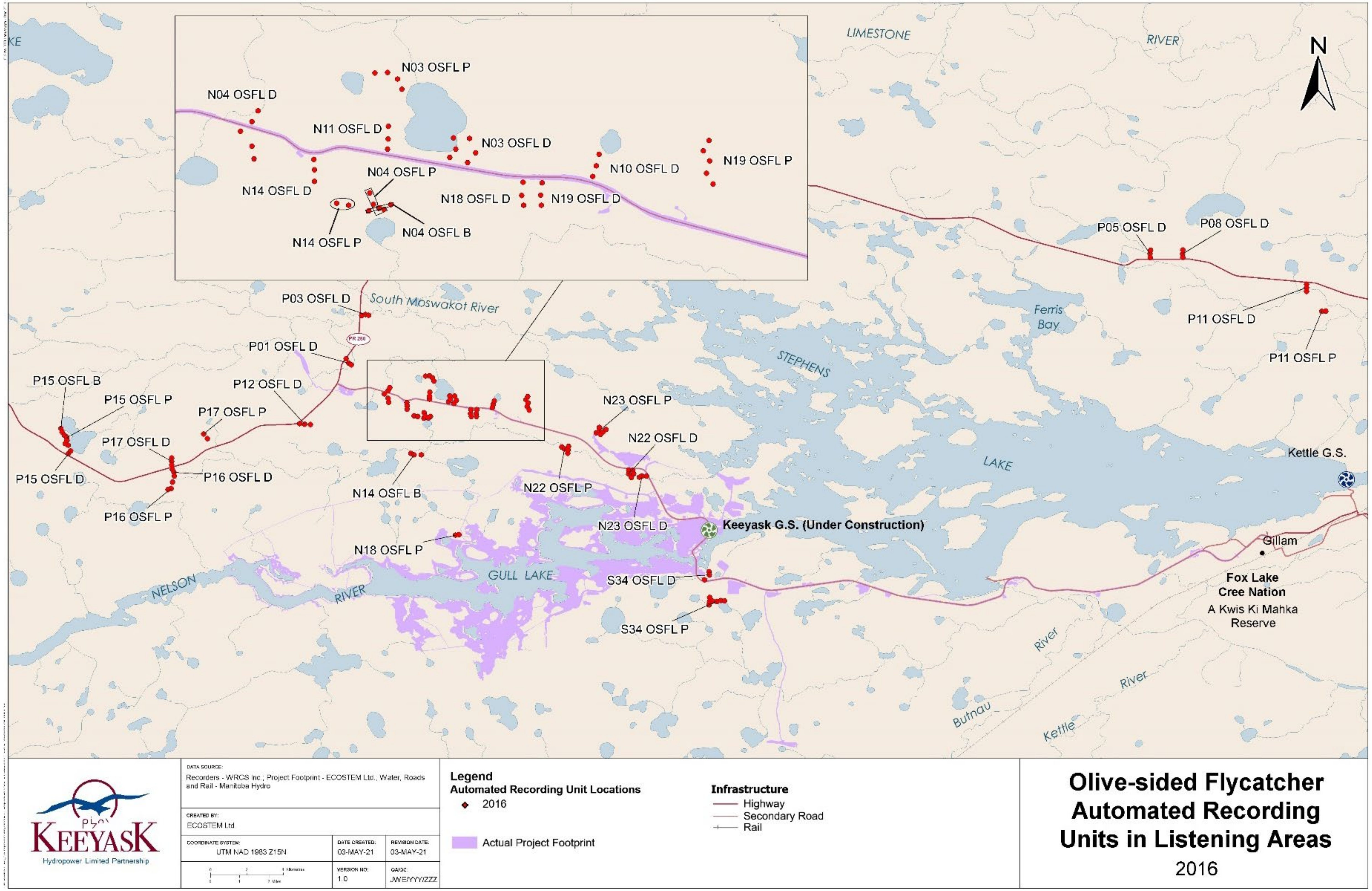
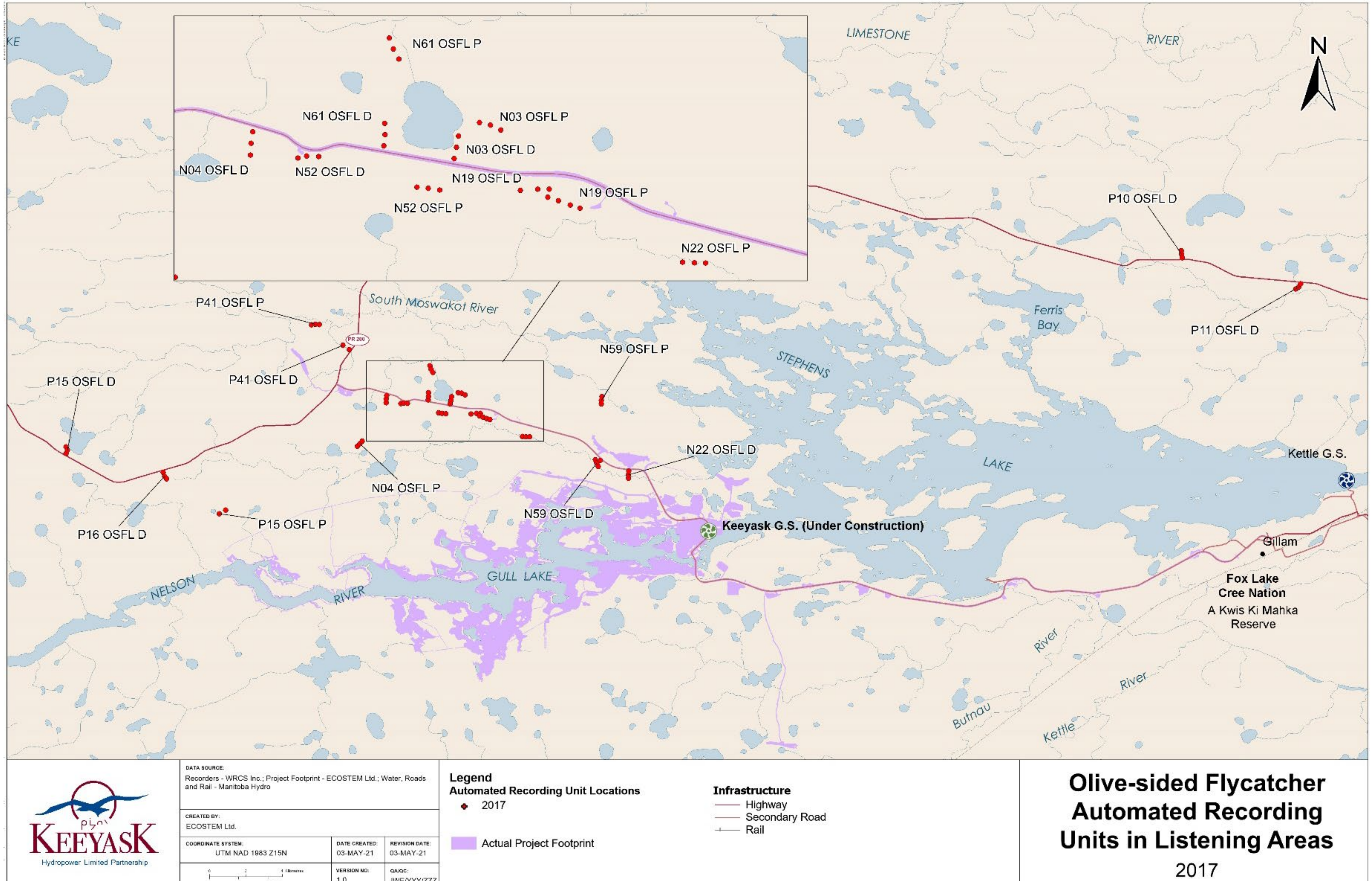


Figure 2-1: Example of ARU placements within a potential bird territory at a disturbed site



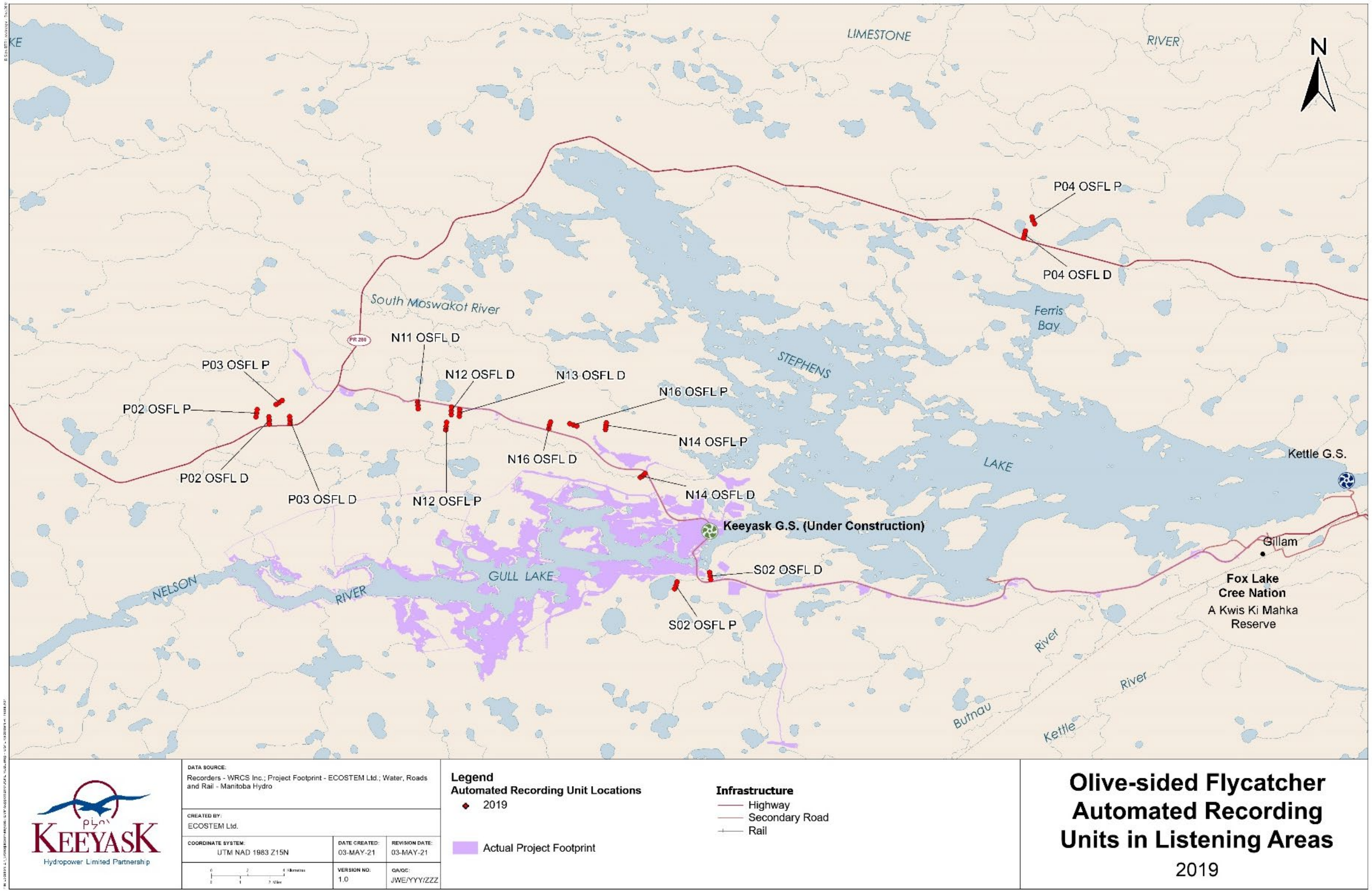
Note: Labels identify unique listening areas (i.e., a potential nesting territory). Letters at the end of the label identify "Project-disturbed" sites ("D"), or reference sites ("P" or "B").

Map 2-2: Olive-sided flycatcher automated recording units in listening areas in 2016



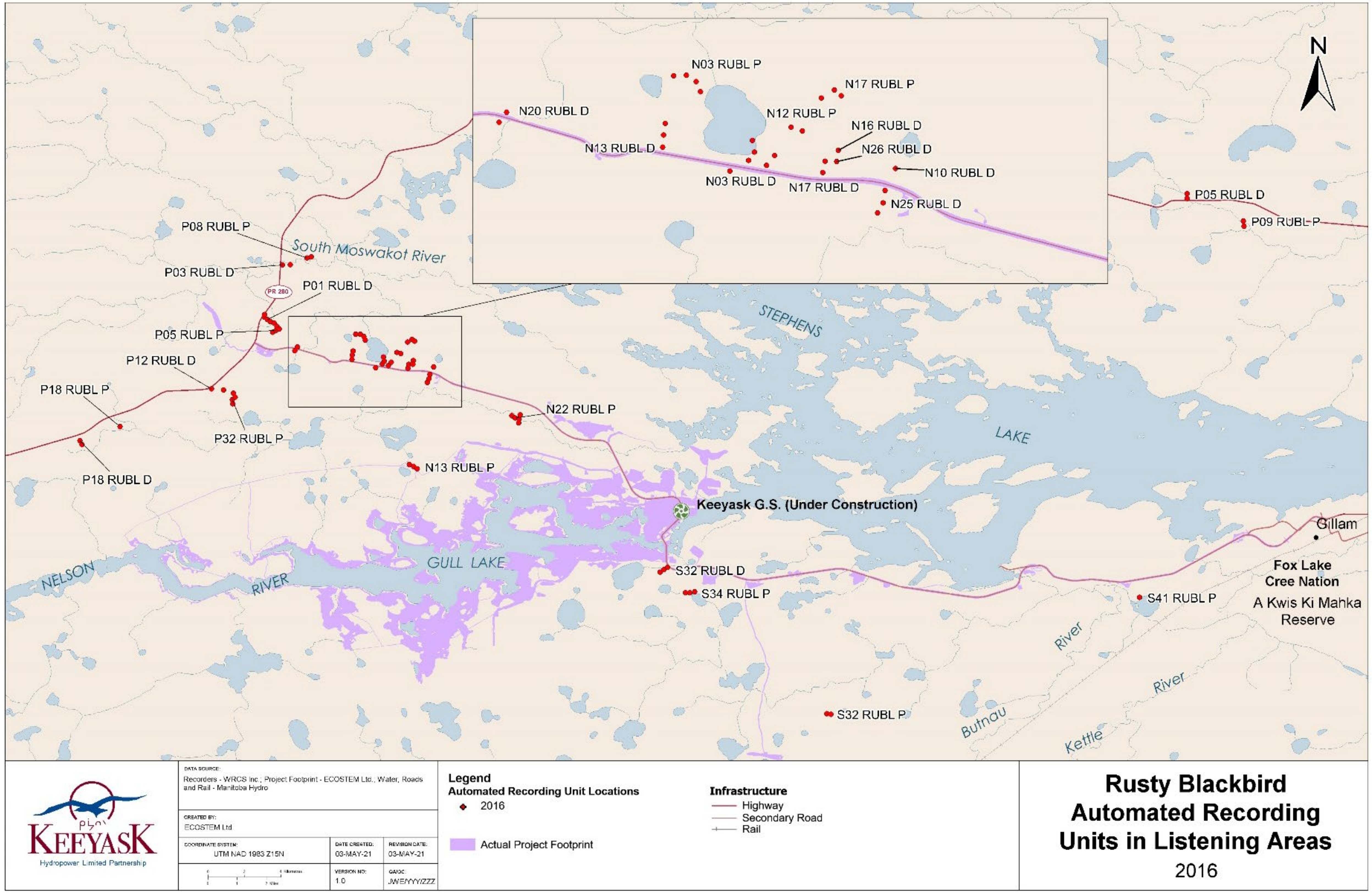
Note: Labels identify unique listening areas (i.e., a potential nesting territory). Letters at the end of the label identify "Project-disturbed" sites ("D"), or reference sites ("P" or "B").

Map 2-3: Olive-sided flycatcher automated recording units in listening areas in 2017



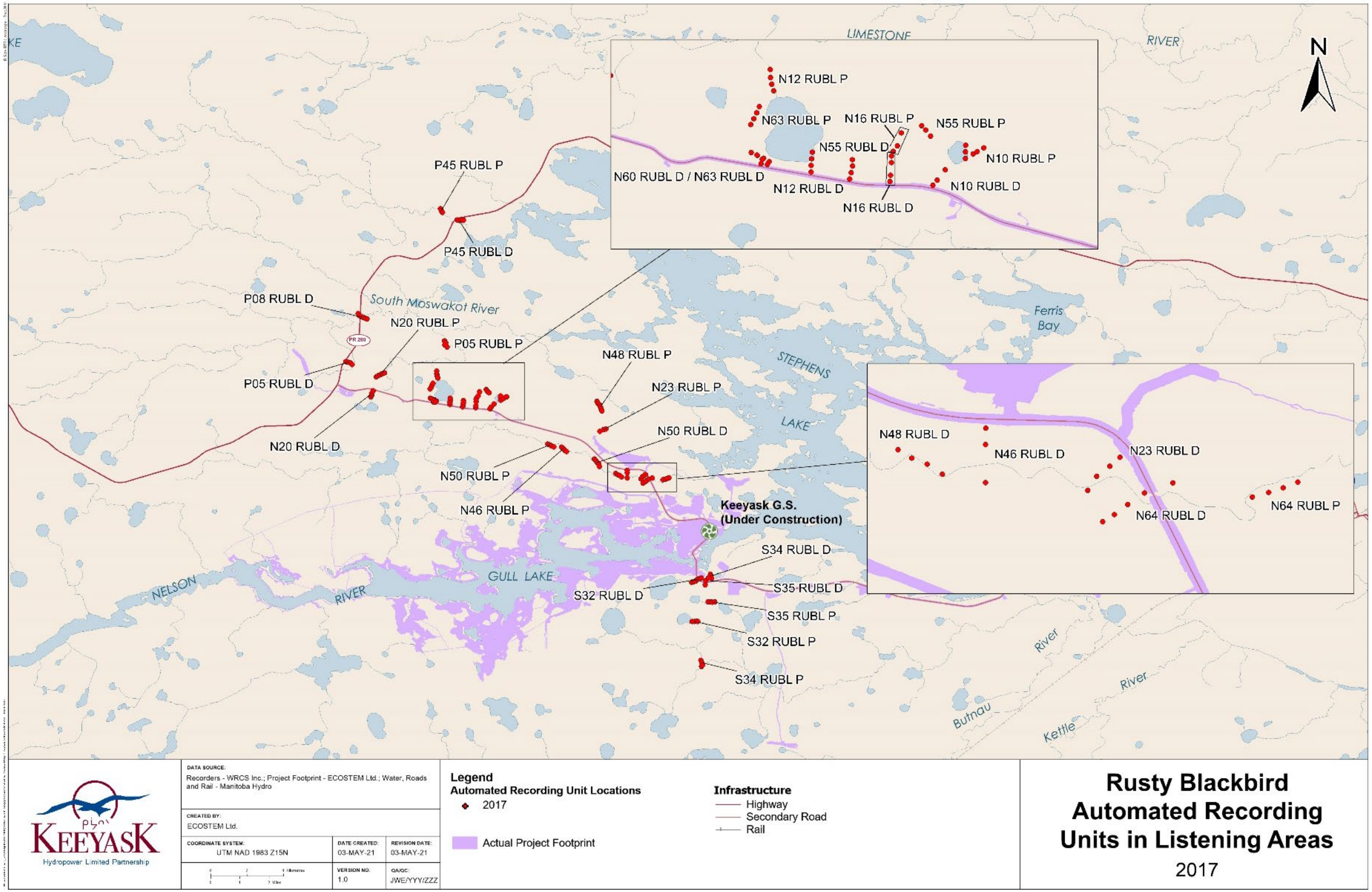
Note: Labels identify unique listening areas (i.e., a potential nesting territory). Letters at the end of the label identify "Project-disturbed" sites ("D"), or reference sites ("P" or "B").

Map 2-4: Olive-sided flycatcher automated recording units in listening areas in 2019



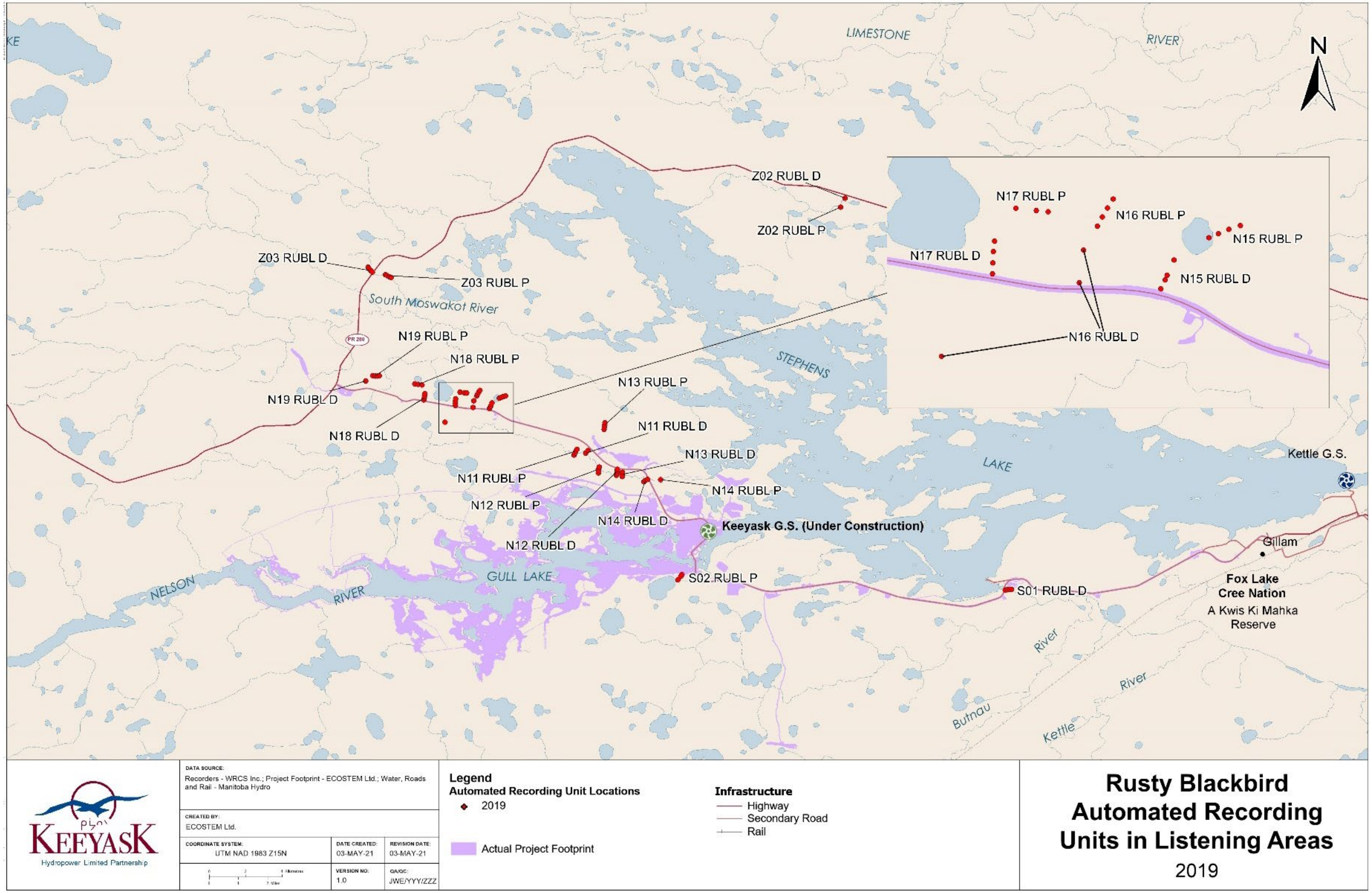
Note: Labels identify unique listening areas (i.e., a potential nesting territory). Letters at the end of the label identify "Project-disturbed" sites ("D"), or reference sites ("P" or "B").

Map 2-5: Rusty blackbird automated recording units in listening areas in 2016



Note: Labels identify unique listening areas (i.e., a potential nesting territory). Letters at the end of the label identify "Project-disturbed" sites ("D"), or reference sites ("P" or "B").

Map 2-6: Rusty blackbird automated recording units in listening areas in 2017



Note: Labels identify unique listening areas (i.e., a potential nesting territory). Letters at the end of the label identify "Project-disturbed" sites ("D"), or reference sites ("P" or "B").

Map 2-7: Rusty blackbird automated recording units in listening areas in 2019

2.2 AUDIO RECORDING SUPPORT AND ANALYSIS

2.2.1 AUDIO PROCESSING

To identify the presence or absence of OSFL or RUBL calls, analyses of bird vocalizations were performed using the statistical package R (Hafner and Katz 2018). For the purposes of this report, the words song and call are used interchangeably; however, for bird identification purposes, the true territorial song of the olive-sided flycatcher (i.e., the distinctive whistled song was famously rendered as '*quick, three beers!'* by early field guide authors) and for rusty blackbird (i.e., song consists of two or three notes, followed by a higher, rising note, like the creak of rusty hinges), were the only two sound types identified using the statistical package R. A stepwise process was used to remove most false positives, where other species were initially identified as the target species. Classification of audio clips involved setting a threshold for target and off-target calls and calculating a difference between the two (see Appendix 1 for detailed analysis methods). All calls identified as OSFL or RUBL were isolated and reviewed for potential false positives not removed during the initial identification process.

Sound pressure level in decibels, or 'sound volume', was used to estimate the distance to a calling bird (Appendix 1). Direction was estimated using the equivalent of Interaural Level Difference. Manually collected bird song samples were used to calibrate the distance and direction to known locations of olive-sided flycatchers and rusty blackbirds. Individuals were georeferenced using GPS. The distance to the observer was estimated using a rangefinder. Samples were collected at about 20 m increasing increments until the bird could no longer be heard. An algorithm was devised to find the peak root mean square amplitude within each clip and convert it to a decibel value with an accurate time stamp. The four peak values were then used to triangulate the direction of the call as measured along the horizontal plane of the microphone array. In the final data set, distance of the calling bird was estimated using decibel-distance curves with the largest decibel value measured by the four microphones.

Future analyses will require the identification of anthropogenic and natural sounds near OSFL or RUBL territories. Sound analyses will be performed using the statistical package R (Hafner and Katz 2018). See Appendix 2 for detailed analysis methods.

2.2.2 DATA ANALYSIS

At the time of this report, data for several aspects of the sensory disturbance and habitat association studies were still in the process of being extracted from the recorder data (Section 2.2.1). Other data, including habitat mapping and interpretation of key habitat attributes, were in preliminary stages. Data analysis for this report focuses on the preliminary descriptive analysis of bird call data for OSFL and RUBL. The results are exploratory and will be used to guide the final analysis once all data become available.

All of the methods described in this section were applied separately for OSFL and RUBL.

The data available for this report included bird call occurrence, including the call date and time; the estimated direction and distance of the call from the recorder; and recorder set time and overall recorder effort, represented by the total number of audio recordings made by the recorder.

For each of the bird species, descriptive analysis was undertaken through the following general steps:

- Data preparation:
  - Validation, cleaning and correction of the raw call and recorder data, including identification of data entry errors, misidentified calls, missing data, and removal of duplicate data.
- Description of overall recorder effort, call detection, and potential recorder issues that would impact the sensory disturbance analysis.
- Map the distribution of calls:
  - Spatial distribution of standardized call density (i.e., heat map). Call density refers to number of calls per unit area per unit time (e.g., number of calls per grid cell per day);
  - Identification of potential breeding pair territories.
- Descriptive analysis of call rates, including daily trends, and trends over the breeding season.

2.2.2.1 DATA PREPARATION

Bird call data were compared with their associated recorder data. Any mismatches between the recorder ID in the bird call data were identified and corrected. Duplicate data were identified by sorting the call data by recorder, date, and time. Calls occurring at the same time, during the same recording, and with identical geographic coordinates were identified as duplicates and filtered from the data.

Individual calls were plotted using their estimated geographic location (i.e., UTM location estimated using distance and direction from recorder location; Section 2.2.1) in a GIS (MapInfo Pro). The distributions of calls were examined for unusual patterns and unexpected locations. Potential errors in position estimates were flagged, the distance and direction estimate calculations were checked for errors, and corrections were applied if justifiable.

Examination of the pattern of call positions around recorders identified a subset of calls with anomalous distributions. Investigation of the raw recorder data determined that a regularly programmed “click” noise produced by the recorder for timing purposes sometimes resulted in false positive calls. A probability score was calculated that identified the likelihood that a call was actually a “click”. Testing determined that selecting a probability score of 0.6 identified clicks 93.5% of the time, with a false positivity rate of only 0.2%. This was selected as the optimal score. All data points with a probability score of 0.6 or greater were filtered from the dataset. Examination of the distribution of the filtered data points confirmed that the anomalous patterns were removed.

As a final step, all calls that were recorded outside of the target listening period for each species were removed from the dataset. Calls may have been recorded outside the target window for the following reasons:

1. They were incidental calls that were detected during the recording windows for other species of interest (i.e., species other than OSFL and RUBL), and
2. Recorder malfunction (e.g., hardware failure causing the time to reset).

Table 2-4 provides the total number of calls for OSFL and RUBL after data preparation for all survey years.

Table 2-4: Territories, recorders[1], and total number of calls in the cleaned datasets for OSFL and RUBL, by survey year

	2016	2017	2019	All
Olive-sided flycatcher				
Possible territories	32	21	16	69
Recorders	104	53	48	205
Calls detected	120,979	50,935	41,475	213,389
Rusty blackbird				
Possible territories	24	34	24	82
Recorders	55	134	75	264
Calls detected	9,535	13,105	13,316	35,956

Notes: [1] The total number of recorders includes only those that detected calls and may be lower than the total number of recorders set for that year (see Table 2-2 and Table 2-3).

2.2.2.2 RECORDER EFFORT

Recorder effort refers to the degree to which a given recorder produced the fully programmed number of valid audio recordings for the total time it was set up in the field. Effort data available for this report were in the form of the total number of full recordings made by each recorder. To complete the full analysis, recorder effort per day is needed. This has been provided for some of the recorders and is in progress for the rest.

Recorders were programmed to produce 66 five-minute recordings in a day (42 recordings during the target listening period for OSFL and RUBL (see Section 1.1.1), and 24 recordings for other species of interest). For example, if a recorder was set for 10 days, and had 100% recorder effort, it should have made 660 five-minute audio recordings. A recorder may have had less than 100% effort due to recorder malfunction (mechanical or battery failure), or the time of day when the recorder was setup and/or removed truncated a recording window.

Data from recorders with more than six days (includes six days plus a portion of the seventh day (e.g., 6.2 days)) of recordings were retained for the data analysis included in this report. In the preliminary study design, seven days was adopted as the minimum number to adequately demonstrate habitat use. Some of the excluded recorders will likely be used in future analyses.

2.2.2.3 LISTENING AREAS AND CALL DISTRIBUTION

A set of automated recording units was located in an area where the target species was confirmed to be perching (see Section 2.1 for methods). These areas represented possible breeding pair territories.

The geographic area within which bird calls could be detected is referred to as the recorder listening area. Recorder listening areas were outlined by buffering the retained recorder location in a given listening area by the 99th percentile distance for the pooled data of the target species in a GIS. The 99th percentile, rather than the maximum distance, was used to account for a degree of positional error inherent in the distance estimator algorithm. The distribution of calls within the areas was represented by a heat map showing the average number of calls per day by location.

Usage of each individual listening area was assessed by calculating the call rate for the area, which was averaged over all ARUs with sufficient effort that were set in the listening area. The call rate for individual ARUs was the total number of calls divided by the total number of days in which recordings were made (calls per day). The period over which calls were detected in the listening areas was determined by the dates of the first and last calls that were detected over the set-up period.

Heat maps were created by tessellating the listening area polygons produced in the step above into 20 m wide (260 m^2) hexagons for each year. Each hexagon was assigned a unique identifier code. The call locations were assigned the identifier code for the hexagon in which they fell. The average number of calls per day was calculated for each hexagon by dividing the total number of calls within the hexagon by the total number of days that the recorder logged data.

2.2.2.4 CALL RATES

For each species, calls were standardized to a mean number of calls per minute. The total number of calls detected in each audio recording was divided by five (the number of minutes in the recording) to obtain the number of calls per minute. These values were averaged over the total number of recordings in the period of interest.

For each recorder, average hourly call rates were calculated by dividing the sum of call rates for the hour by six (the total number of five-minute recording periods per hour) to get an overall average for the hour. Average daily call rates were calculated by averaging the hourly call rates over a given day.

These calculations assume that in a given recording day, all the programmed recordings were produced. In cases where the recorder did not obtain the full number of recordings in a day, the calculated averages may be over or underestimated. Standardization will remove these biases. For this preliminary exploratory analysis, it was not expected that missing recordings were widespread enough to substantially influence the patterns.

Descriptive statistics showing average trends in call rates within the daily target time window, as well as over the recording period, were produced. To standardize the results and avoid emphasizing outliers, data were truncated to remove dates that were only captured by recorders in a single territory.

3.0 RESULTS

3.1 OLIVE-SIDED FLYCATCHER

3.1.1 RECORDER EFFORT

Recorder percent effort ranged from 0% to 100% across the three survey years. The year with the overall lowest recorder effort was 2016, with an overall average of 60% (Table 3-1). The overall average recorder effort in 2017 and 2019 was 89% and 96%, respectively.

Based on the total number of recordings, 53 (45%) of the recorders in 2016 were considered to have low effort (six or fewer days worth of recording data; Table 3-1). In 2017, eight (13%) of the recorders had low effort, while in 2019, no recorders had low effort.

Of the recorders set in 2016, 104 (88%) detected at least one OSFL call (Table 3-1). In 2017, 53 (84%) of the recorders detected calls, and 48 (96%) detected calls in 2019.

Due to the overall low effort of many recorders in 2016 and recorder effort data still to come, standardization of those data to produce heat maps and call rates was not completed. Consequently, the 2016 call data were excluded from the heat map and call rate analysis for this report.

Table 3-1: Recorder effort and call detection for olive-sided flycatcher by survey year

Metric	2016	2017	2019
Total number of ARUs	118	63	50
Average percent effort[1]	60.1	88.7	96.5
Number of ARUs with low effort[2]	53	8	0
Percent of ARUs that detected calls	88.1	84.1	96.0

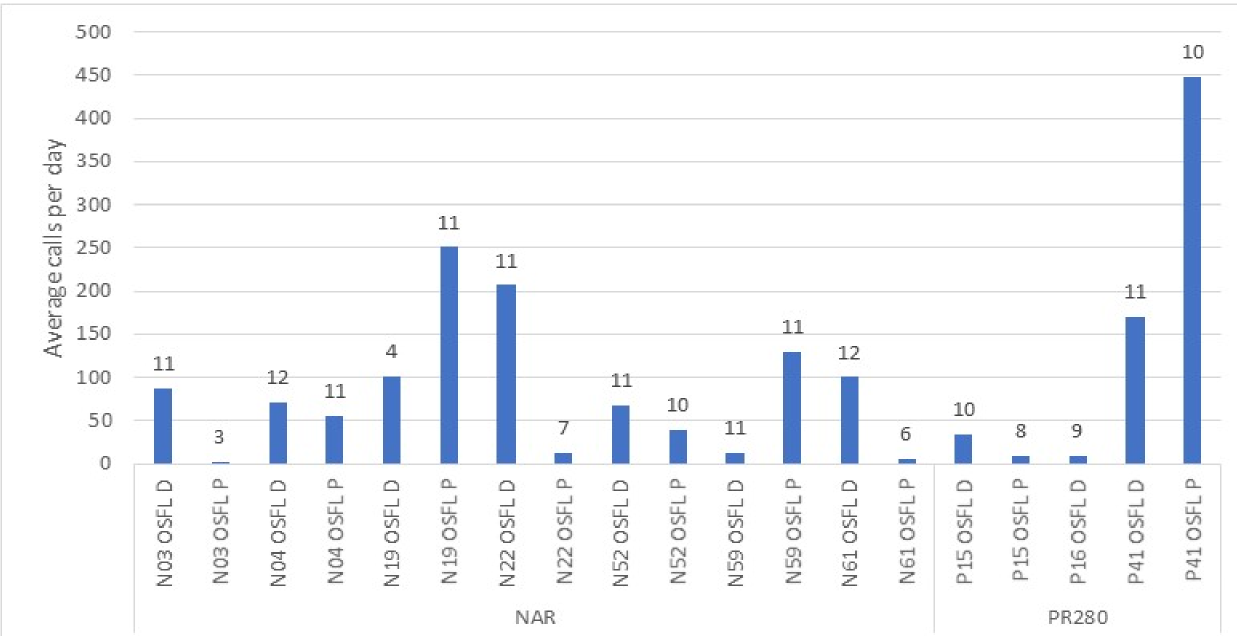
Notes: [1] Mean percent of set-period in which the ARU made recordings. Ten days of recordings or more = 100% effort. [2] ARUs with six or fewer days of full recordings.

3.1.2 LISTENING AREAS AND CALL DISTRIBUTION

Individual ARUs detected OSFL calls up to a distance of approximately 314 m, forming a circular listening area of approximately 31 ha. OSFL use of the listening areas varied across the ARUs. Considering only the ARUs that detected OSFL calls, the average number of calls during the total daily recording time (i.e., 210 minutes for a recorder with full effort during the target listening period) in each listening area in 2017 (Figure 3-1) ranged from a minimum of less than 2 calls/day

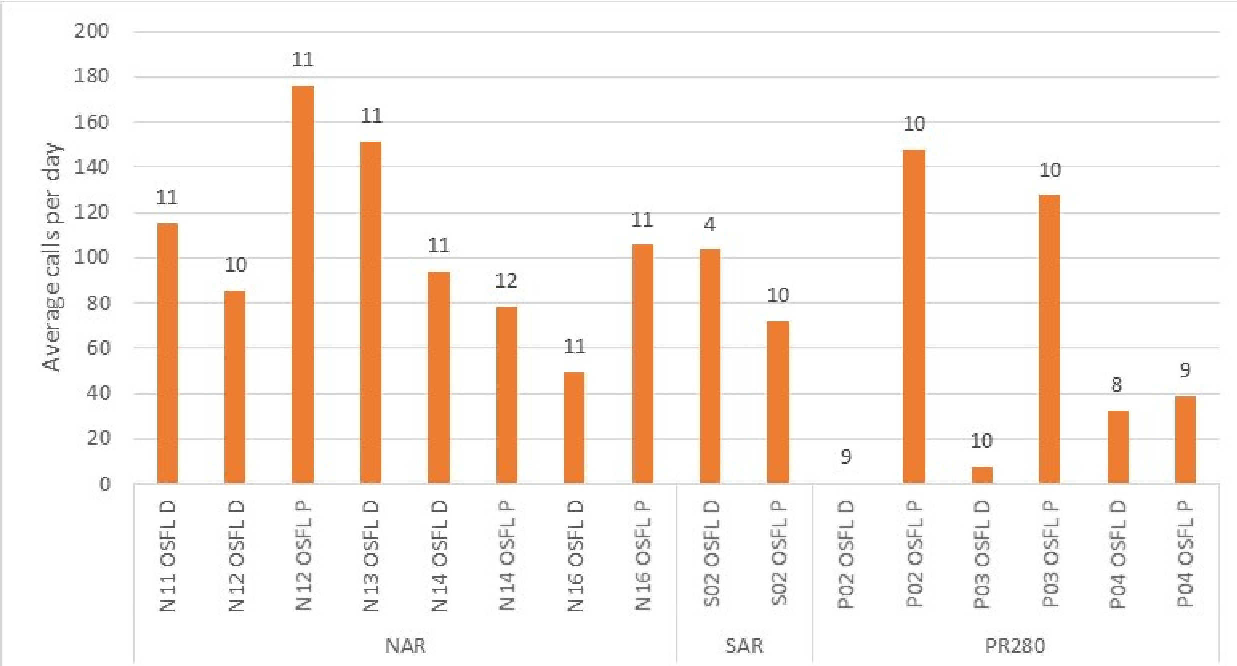
(N03 OSFL P) to a maximum of 448 calls/day (P41 OSFL P). The time span between the first and last detected calls within the listening areas ranged from approximately 3 days to 12 days.

In 2019, the average number of calls per day (Figure 3-2) ranged from a minimum of less than one (P02 OSFL D) to a maximum of 176 (N12 OSFL P). The time span between the first and last detected calls within the listening areas ranged from approximately 4 days to 12 days.



Notes: NAR = North Access Road; PR280 = Provincial Road 280. Labels identify unique listening areas (i.e. a potential nesting territory). Letters at the end of the label identify "Project-disturbed" sites ("D"), or reference sites ("P" or "B").

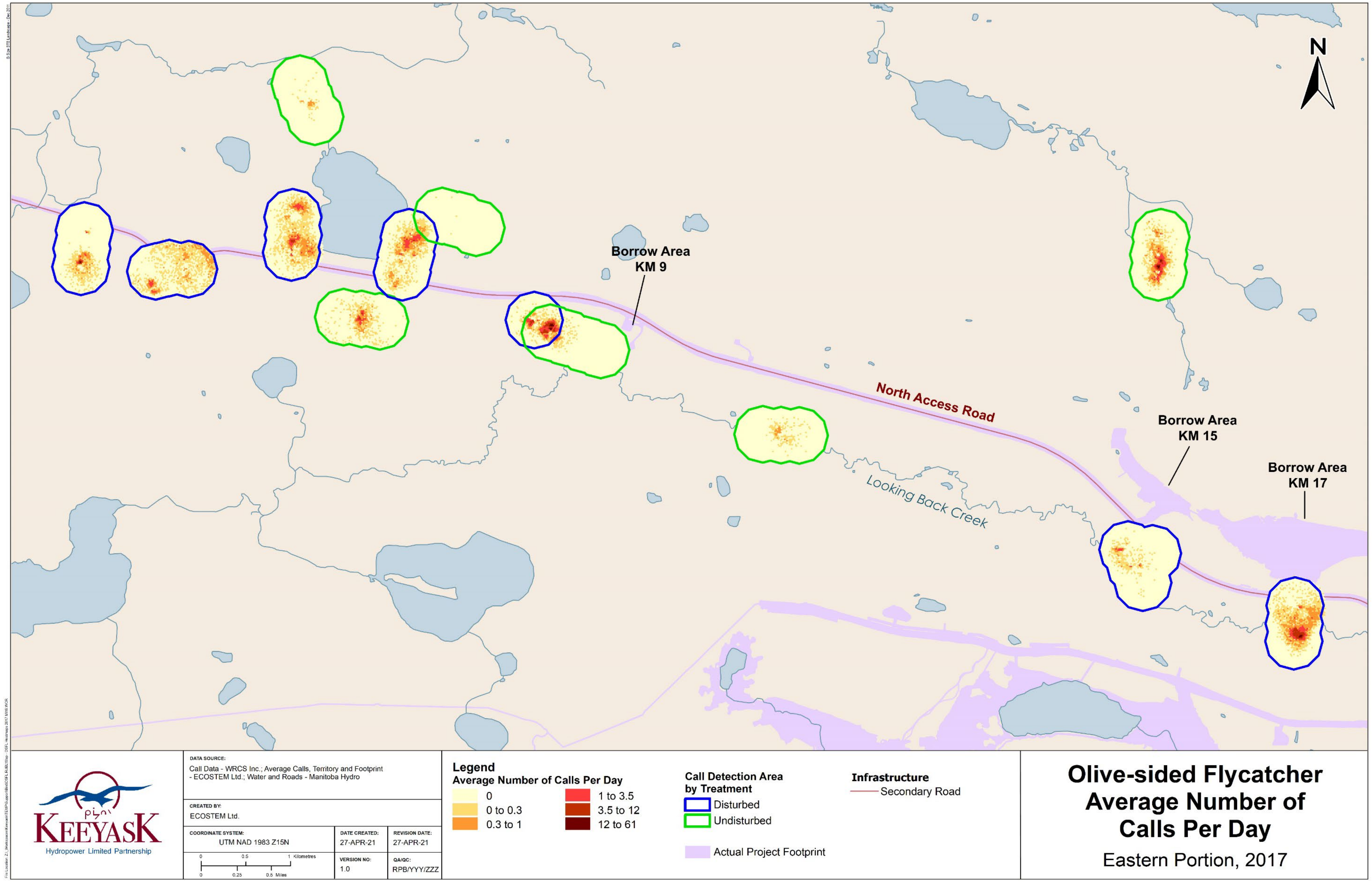
Figure 3-1: Average number of OSFL calls per day by listening area in 2017. Numbers above the bars represent the number of days between the first and last detected calls. Includes all recorders active for more than six days.



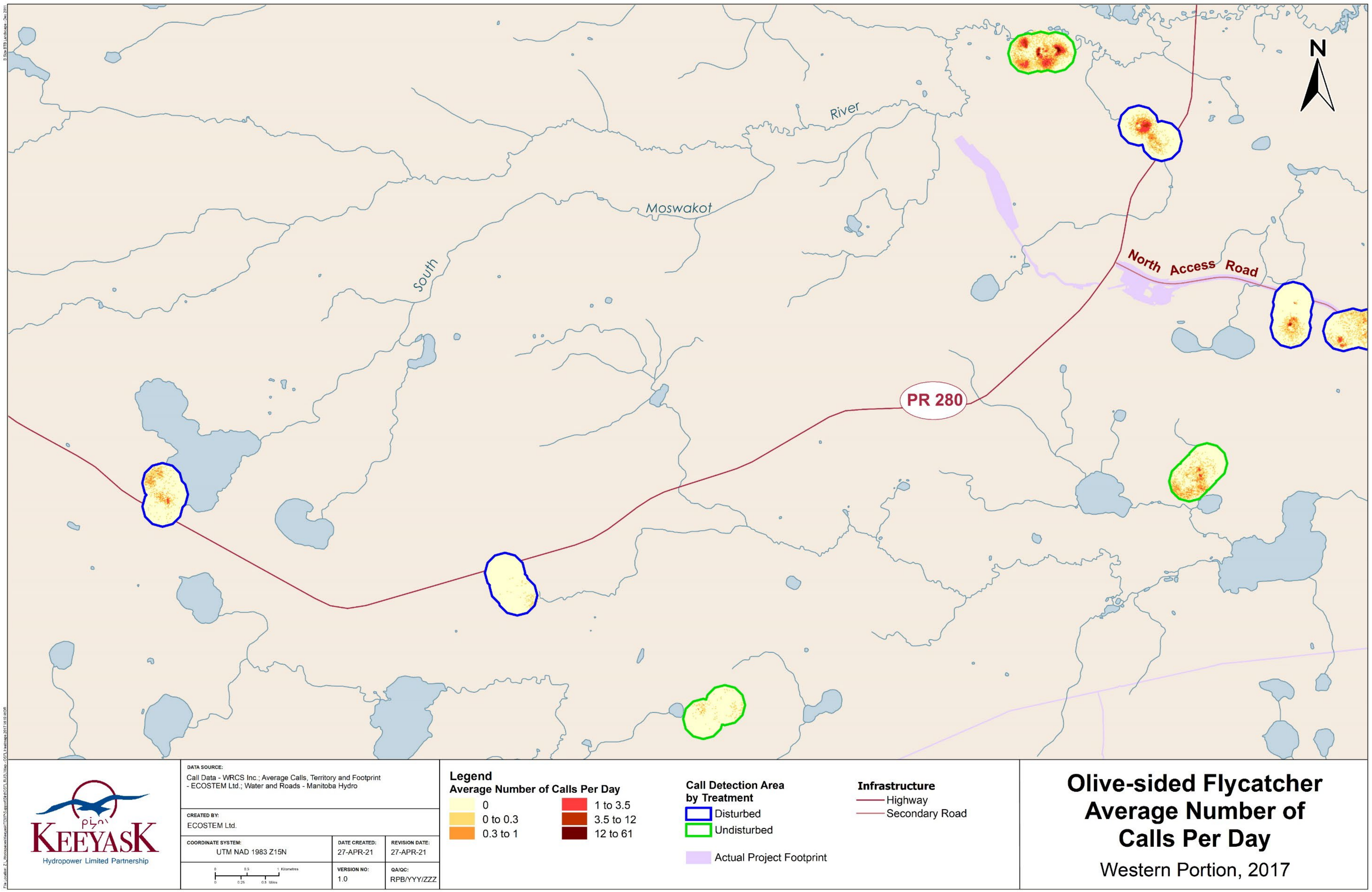
Notes: NAR = North Access Road; SAR = South Access Road; PR280 = Provincial Road 280. Labels identify unique listening areas (i.e. a potential nesting territory). Letters at the end of the label identify "Project-disturbed" sites ("D"), or reference sites ("P" or "B").

Figure 3-2: Average number of OSFL calls per day by listening area in 2019. Numbers above the bars represent the number of days between the first and last detected calls. Includes all recorders active for more than six days.

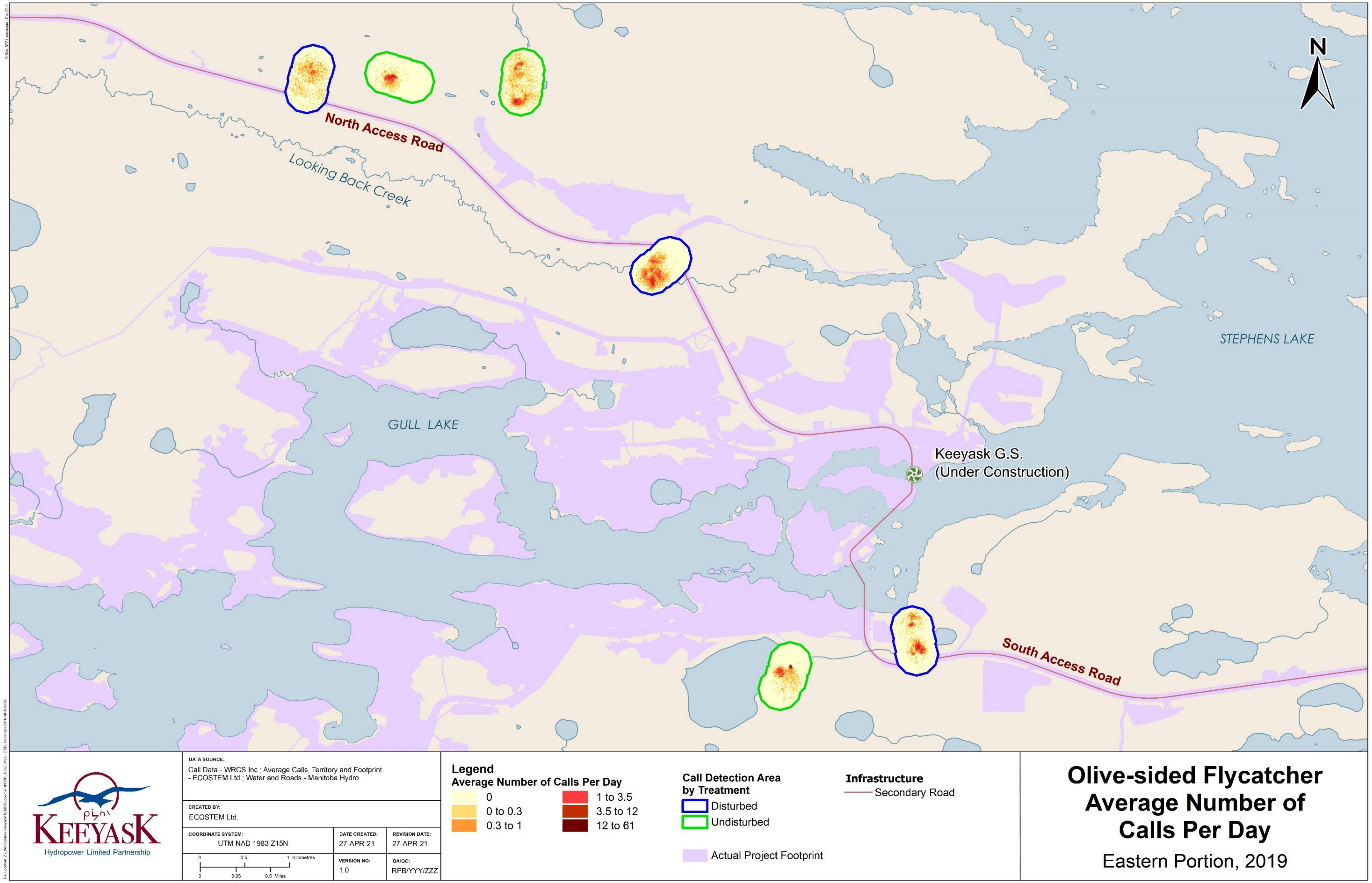
Map 3-1 to Map 3-4 show heat maps of the average number of calls per day throughout the recorder listening areas. As expected, the heat maps show that the distribution of calls was uneven throughout the listening area for both 2017 and 2019. Most listening areas contained one or more "hot spots", where calls were more frequently occurring, while other portions of the listening areas had few to no calls over the recording period. There were hot spots and areas with few or no calls in disturbed and undisturbed listening areas. By design, all disturbed listening areas near the NAR and SAR overlapped the access roads to some extent.



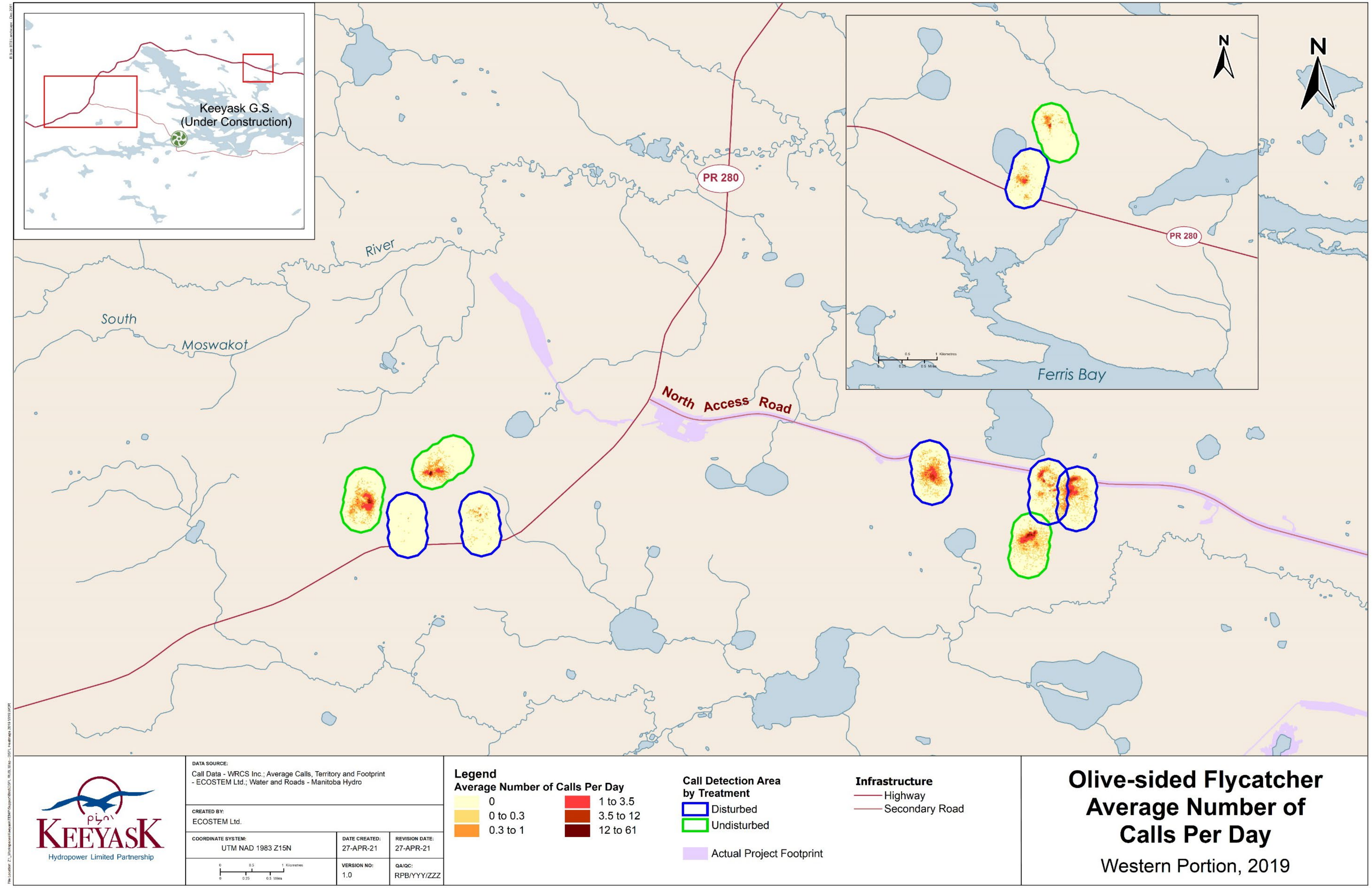
Map 3-1: **Distribution of olive-sided flycatcher in eastern listening areas in 2017**



Map 3-2: Distribution of olive-sided flycatcher in western listening areas in 2017



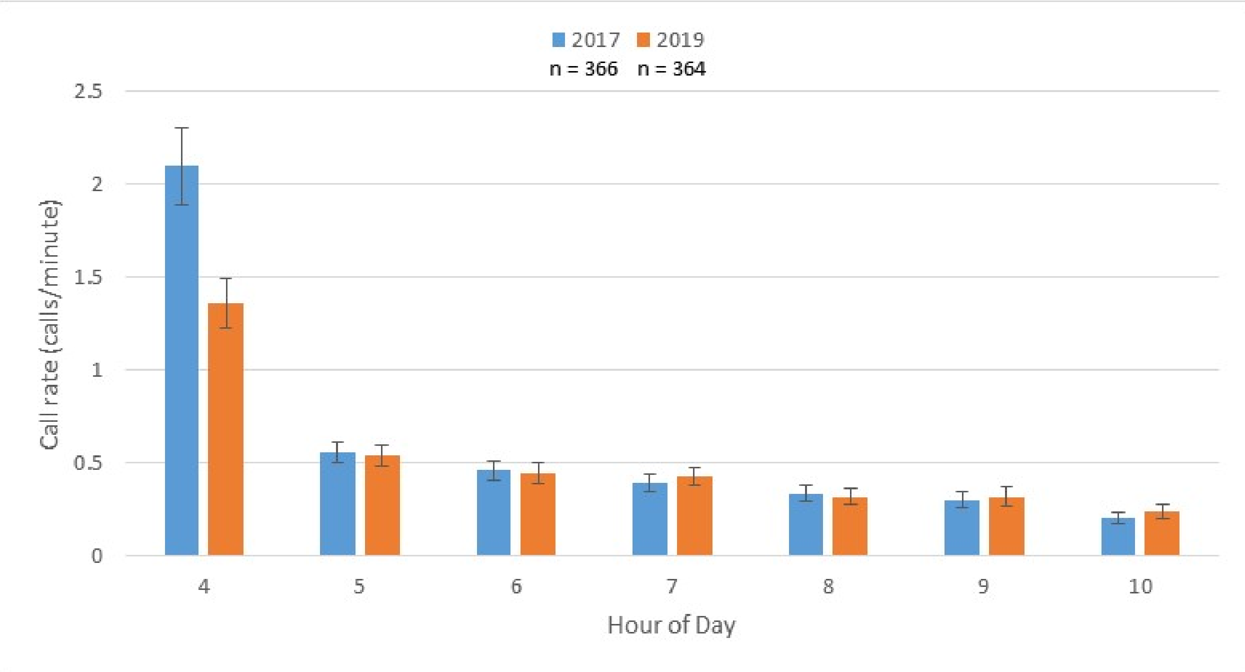
Map 3-3: Distribution of olive-sided flycatcher in eastern listening areas in 2019



Map 3-4: Distribution of olive-sided flycatcher in western listening areas in 2019

3.1.3 CALL RATES

The average call rate (calls/minute) for OSFL varied over the morning (i.e., 4 AM to 11 AM; Figure 3-3). The average call rate was considerably higher between 4 AM and 5 AM than during the rest of the morning. The call rate between 4 AM and 5 AM was approximately 2.1 calls/minute in 2017 and 1.4 calls/minute in 2019. In both years, the call rate then decreased to just over 0.5 calls per minute between 5 AM and 6 AM, and to approximately 0.2 calls per minute between 10 AM and 11 AM.

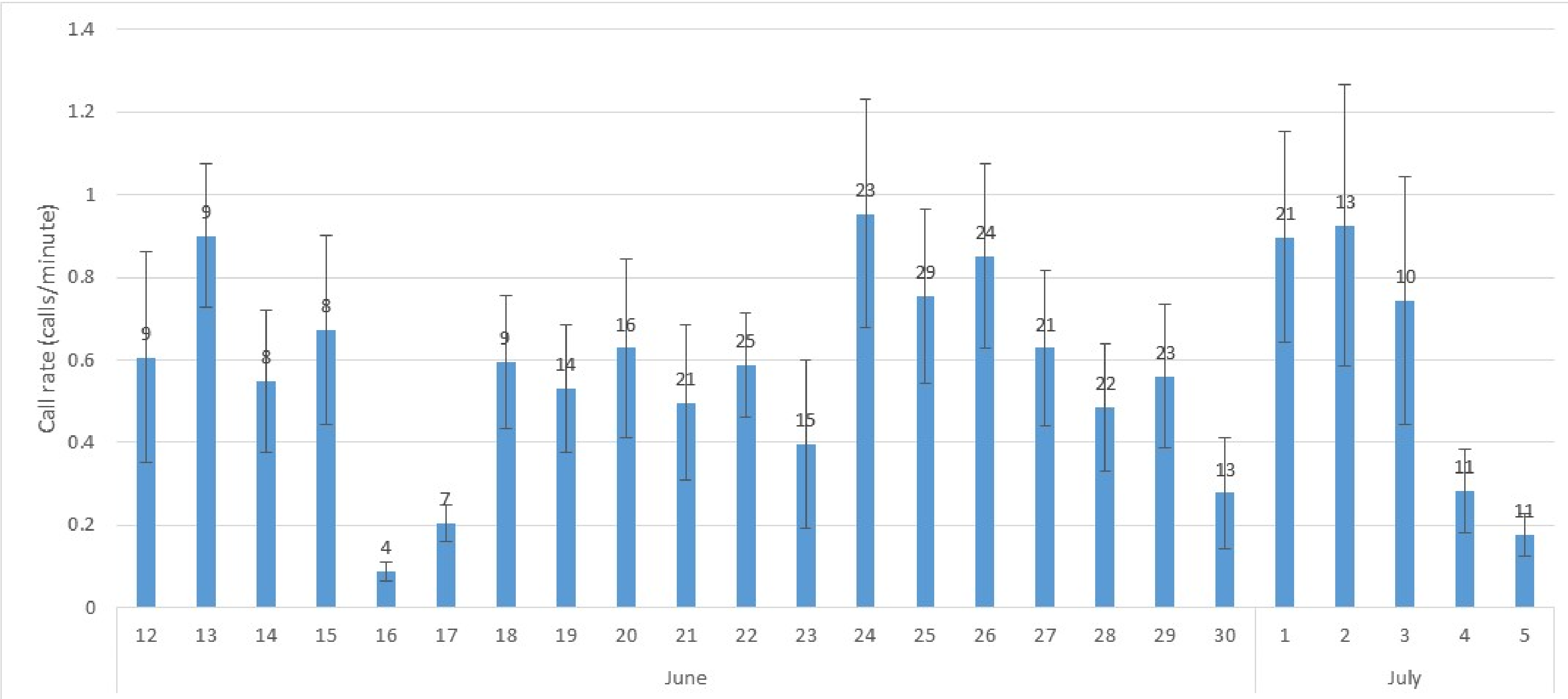


Notes: n = the number of recorders plus the cumulative number of recording days over the monitoring period.

Figure 3-3: Average call rate of OSFL by hour over the 2017 and 2019 monitoring periods. Error bars represent the standard error of the mean.

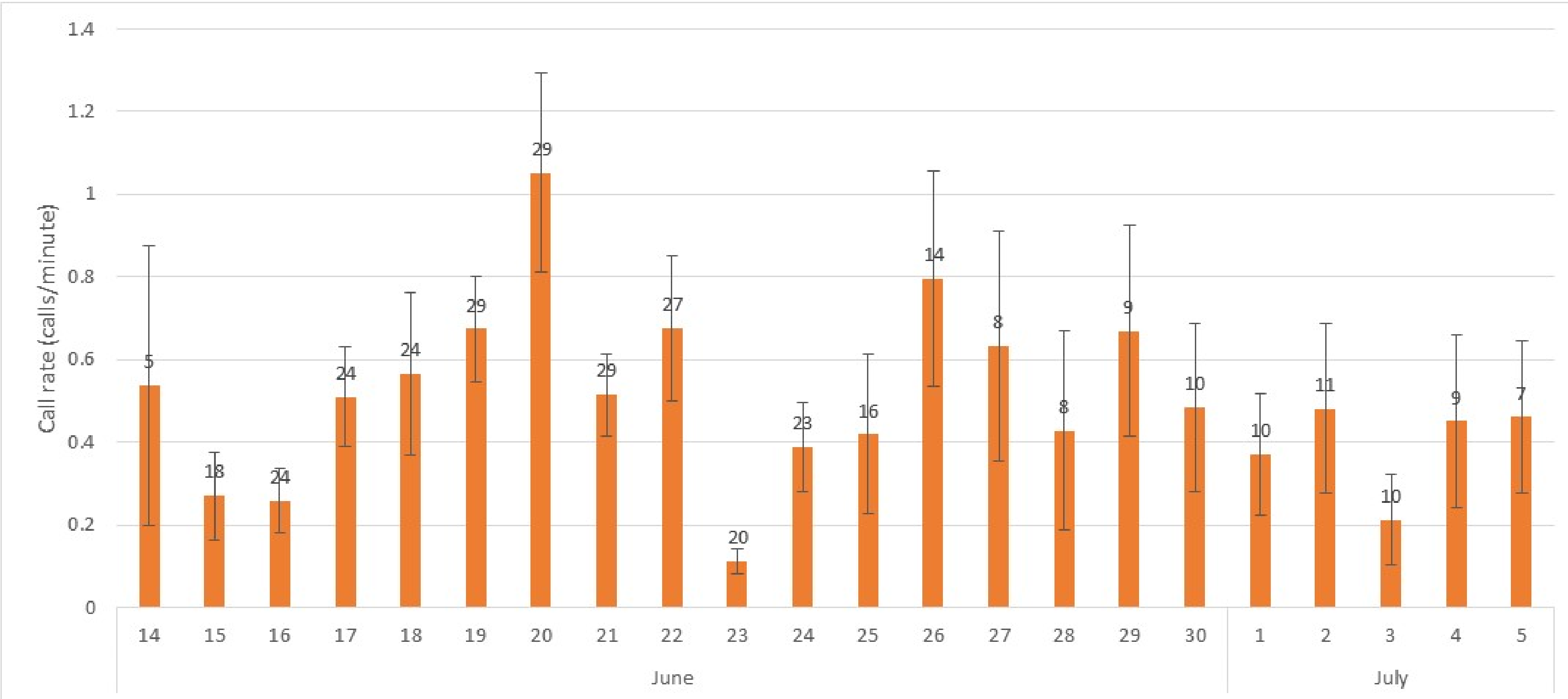
The day-to-day variation in the average daily call rate ranged by an order of magnitude over the monitoring period for both 2017 and 2019 (Figure 3-4 and Figure 3-5). In 2017, average call rates over the day ranged from a minimum of 0.1 calls/minute (Julian day 167, or June 16) to a maximum of 1.0 calls per minute (Julian day 175, or June 24). In 2019, average call rates over the day ranged from a minimum of 0.1 calls/minute (Julian day 174, or June 23) to a maximum of 1.1 calls/minute (Julian day 171, or June 20).

Daily average call rates over the 2017 or 2019 monitoring periods did not show any trends or other patterns (Figure 3-4 and Figure 3-5). The patterns for 2017 and 2019 were not similar.



Note: Numbers in error bars represent the number of recorders with call data on that day.

Figure 3-4: Average call rate of OSFL by day over the 2017 monitoring period. Error bars represent the standard error of the mean



Note: Numbers in error bars represent the number of recorders with call data on that day.

Figure 3-5: Average call rate of OSFL by day over the 2019 monitoring period. Error bars represent the standard error of the mean

3.2 RUSTY BLACKBIRD

3.2.1 RECORDER EFFORT

Automatic recording unit percent effort ranged from 0% to 100% across the three survey years. The year with the lowest overall recorder effort was 2016, with an overall average of 55% (Table 3-2). The overall average recorder effort in 2017 and 2019 was 94% and 92%, respectively.

Based on the total number of recordings, 39 (56%) of the ARUs in 2016 were considered to have low effort (six or fewer days worth of recording data; Table 3-2). In 2017, seven (5%) of the ARUs had low effort, while in 2019, five (7%) had low effort.

Of the ARUs set in 2016, 55 (79%) detected at least one RUBL call (Table 3-2). In 2017, 134 (96%) of the recorders detected calls, and 75 (99%) detected calls in 2019.

Due to the low overall effort of many recorders in 2016 and recorder effort data still to come, standardization of that data to produce heat maps and call rates was not completed. Consequently, the 2016 call data were excluded from the heat map and call rate analysis for this report.

Table 3-2: Recorder effort and call detection for rusty blackbird by survey year

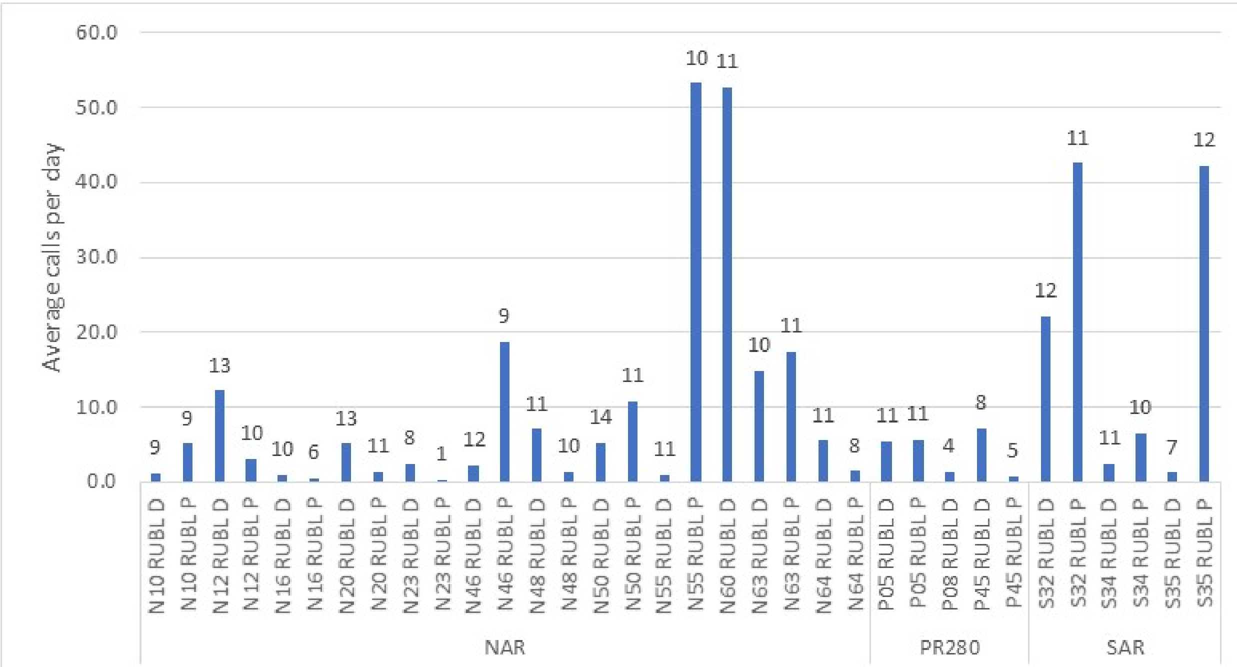
Metric	2016	2017	2019
Total number of ARUs	70	140	76
Average percent effort[1]	54.5	94.0	92.1
Number of ARUs with low effort[2]	39	7	5
Percent of ARUs that detected calls	78.6	95.7	98.7

Notes: [1] Mean percent of set-period in which the ARU made recordings. Ten days of recordings or more = 100% effort. [2] ARUs with six or fewer days of full recordings.

3.2.2 LISTENING AREAS AND CALL DISTRIBUTION

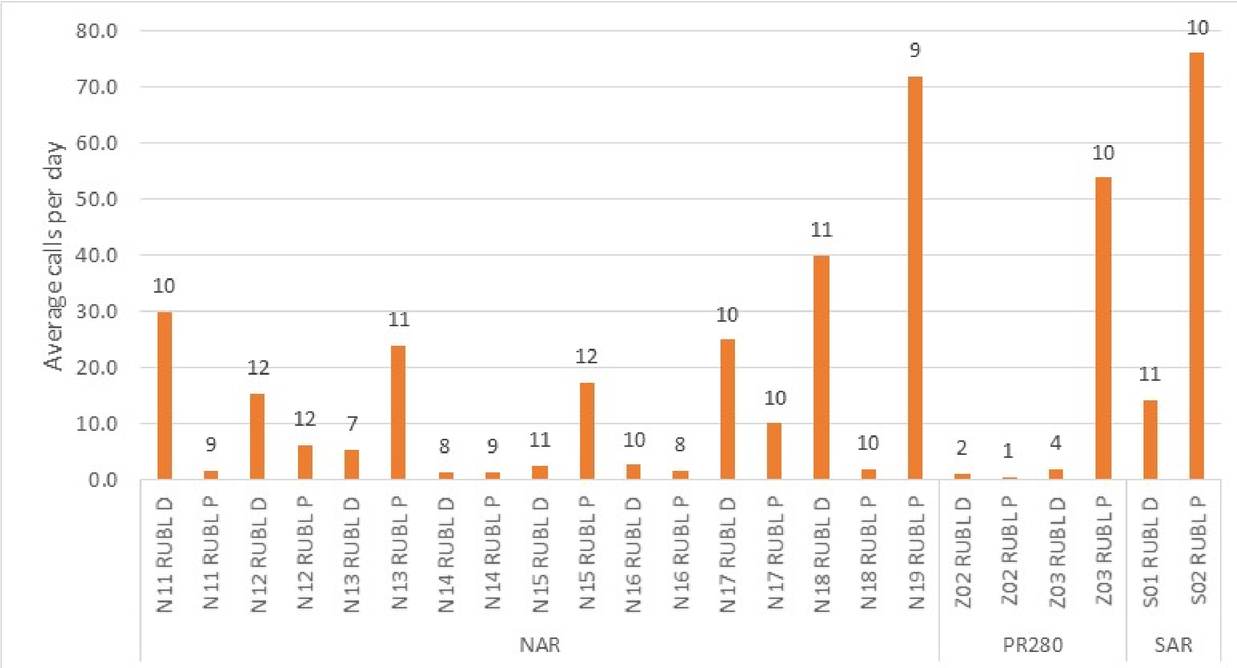
Individual ARUs detected RUBL calls up to a distance of approximately 57 m, forming a circular listening area of just over 1 ha. RUBL use of the listening areas varied across the ARUs. Considering only the recorders that detected RUBL calls, the average number of calls during the total daily recording time (i.e., 210 minutes for a recorder with full effort) in each listening area in 2017 (Figure 3-6) ranged from a minimum of less than 0.5 calls/day (N23 RUBL P) to a maximum of 53 calls/day (N55 RUBL P). The time span between the first and last detected calls within the listening areas ranged from approximately 1 day to 14 days.

In 2019, the average number of calls per day (Figure 3-7) ranged from a minimum of less than 1 (Z02 RUBL P) to a maximum of 76 (S02 RUBL P). The time span between the first and last detected calls within the listening areas ranged from approximately 1 day to 12 days.



Notes: NAR = North Access Road; PR280 = Provincial Road 280. Labels identify unique listening areas (i.e. a potential nesting territory). Letters at the end of the label identify "Project-disturbed" sites ("D"), or reference sites ("P" or "B").

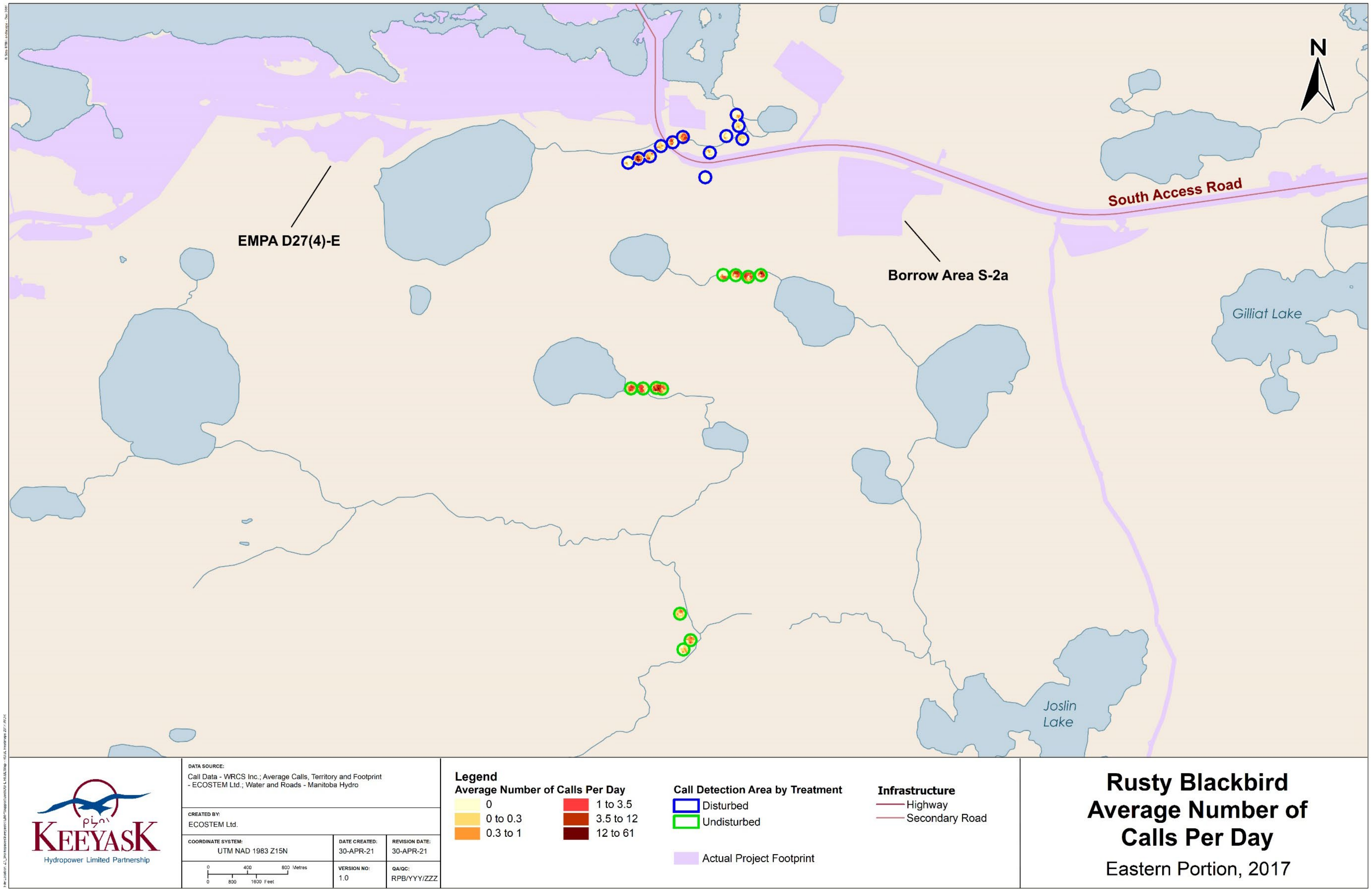
Figure 3-6: Average number of RUBL calls per day by listening area in 2017. Numbers above the bars represent the number of days between the first and last detected calls. All recorders active for more than six days.



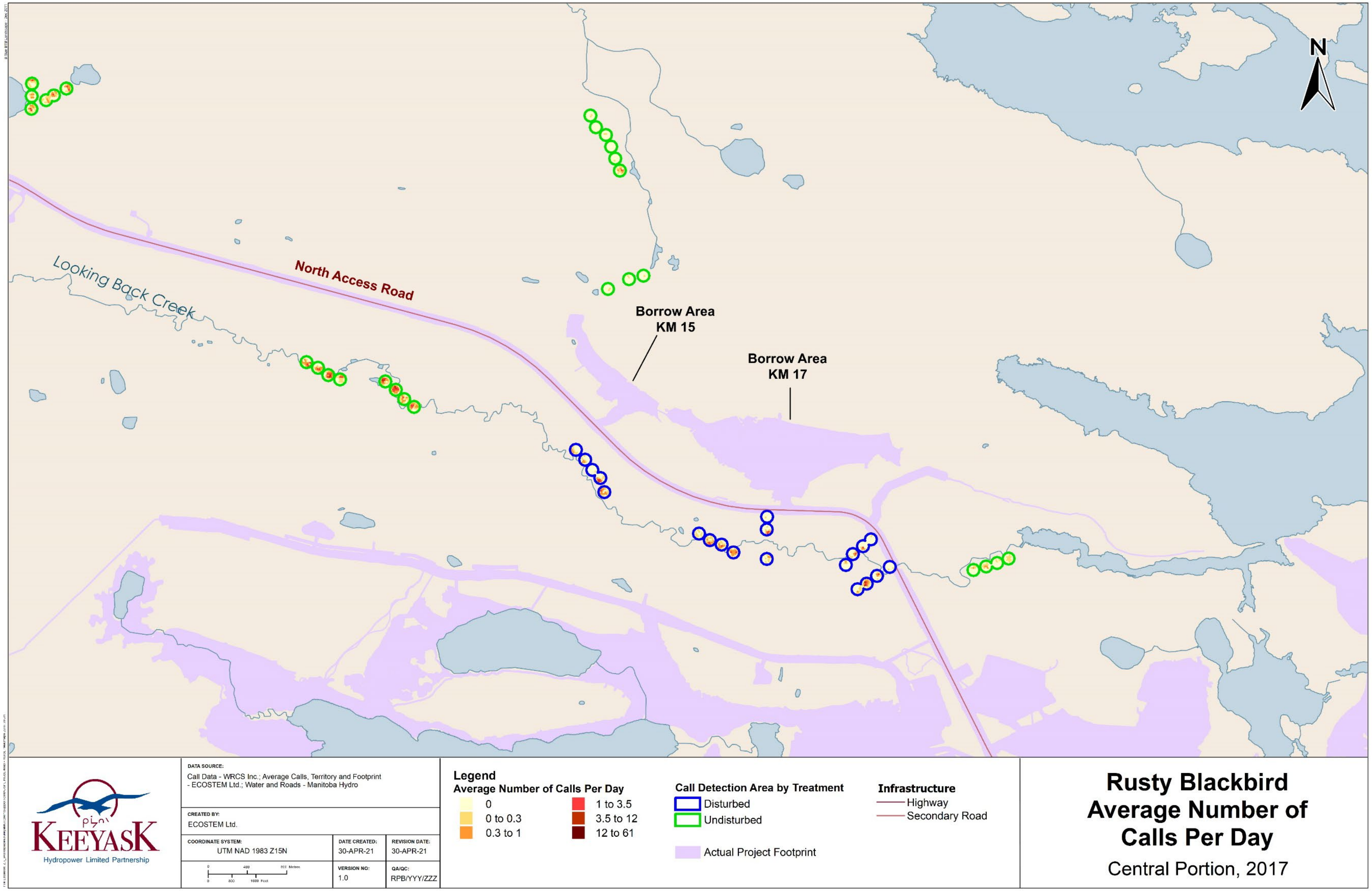
Notes: NAR = North Access Road; SAR = South Access Road; PR280 = Provincial Road 280. Labels identify unique listening areas (i.e. a potential nesting territory). Letters at the end of the label identify "Project-disturbed" sites ("D"), or reference sites ("P" or "B").

Figure 3-7: Average number of RUBL calls per day by listening area in 2019. Numbers above the bars represent the number of days between the first and last detected calls. All recorders active for more than six days.

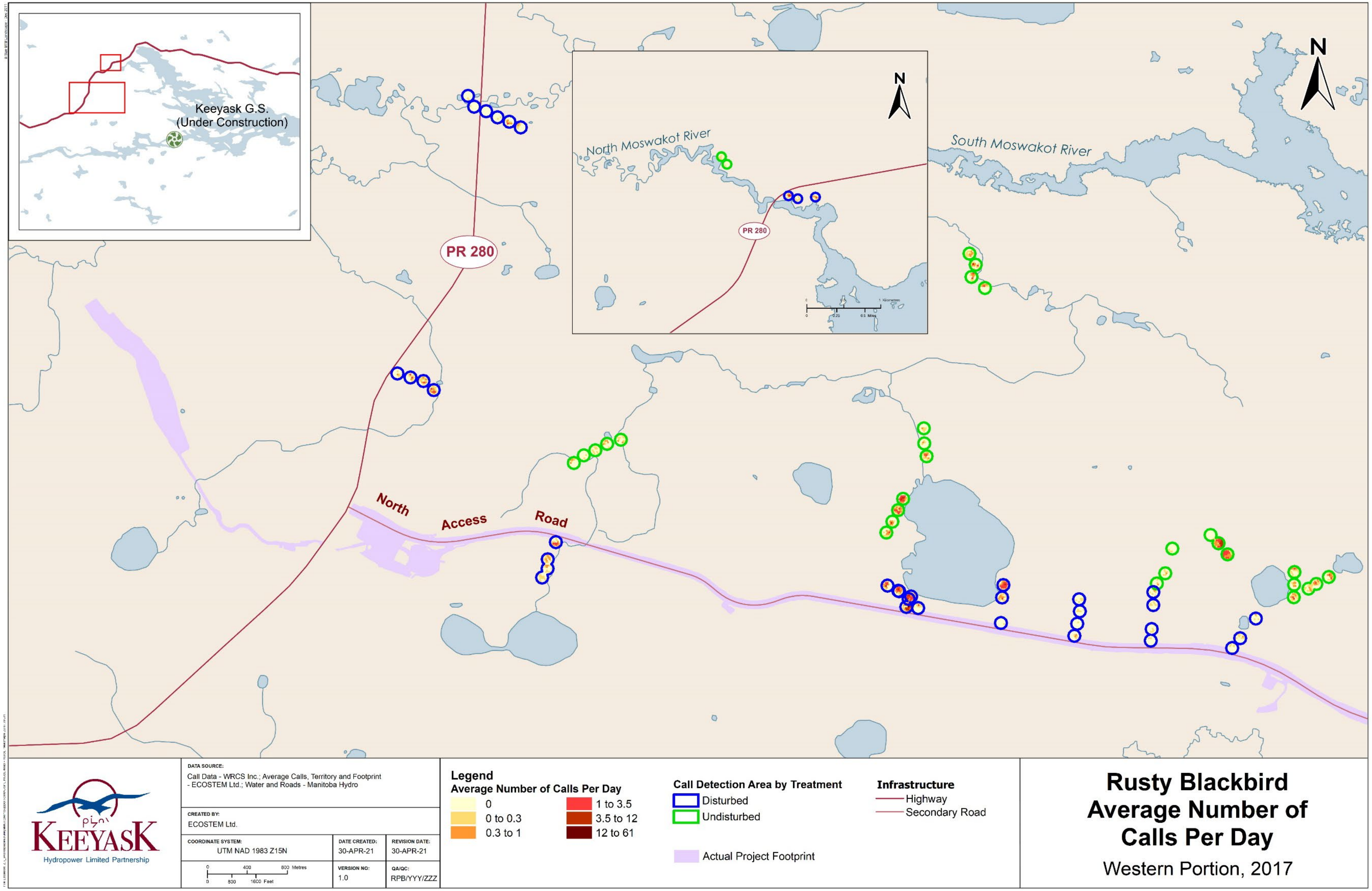
Map 3-5 to Map 3-10 show heat maps of the average number of calls per day throughout the recorder listening areas. As expected, the heat maps show that the distribution of calls was uneven throughout the listening area for both 2017 and 2019. Most listening areas contained one or more "hot spots", where calls were more frequently occurring, while other portions of the listening areas had few to no calls over the recording period. There were hot spots and areas with few or no calls in disturbed and undisturbed listening areas.



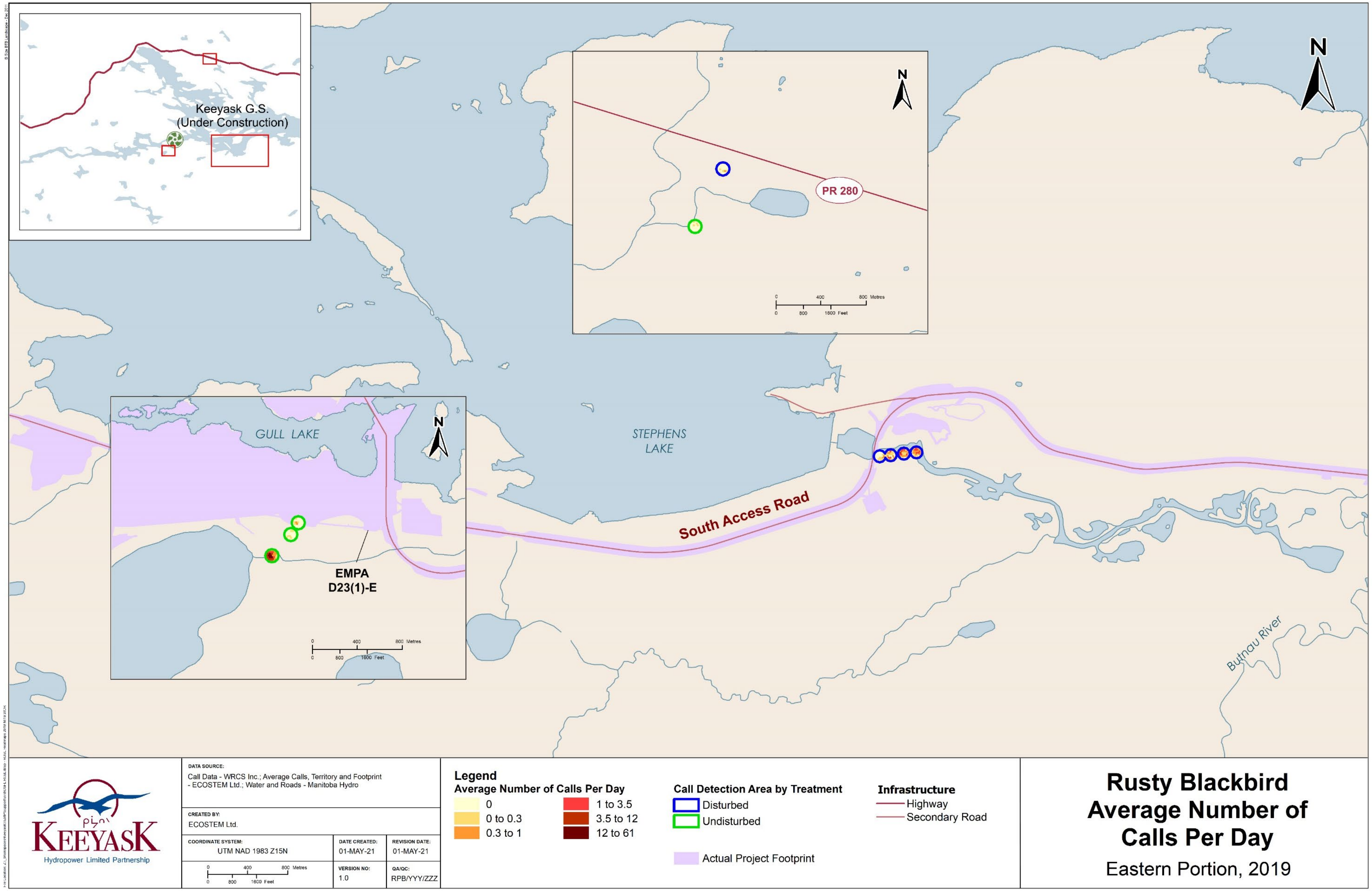
Map 3-5: **Distribution of rusty blackbird in eastern listening areas in 2017**



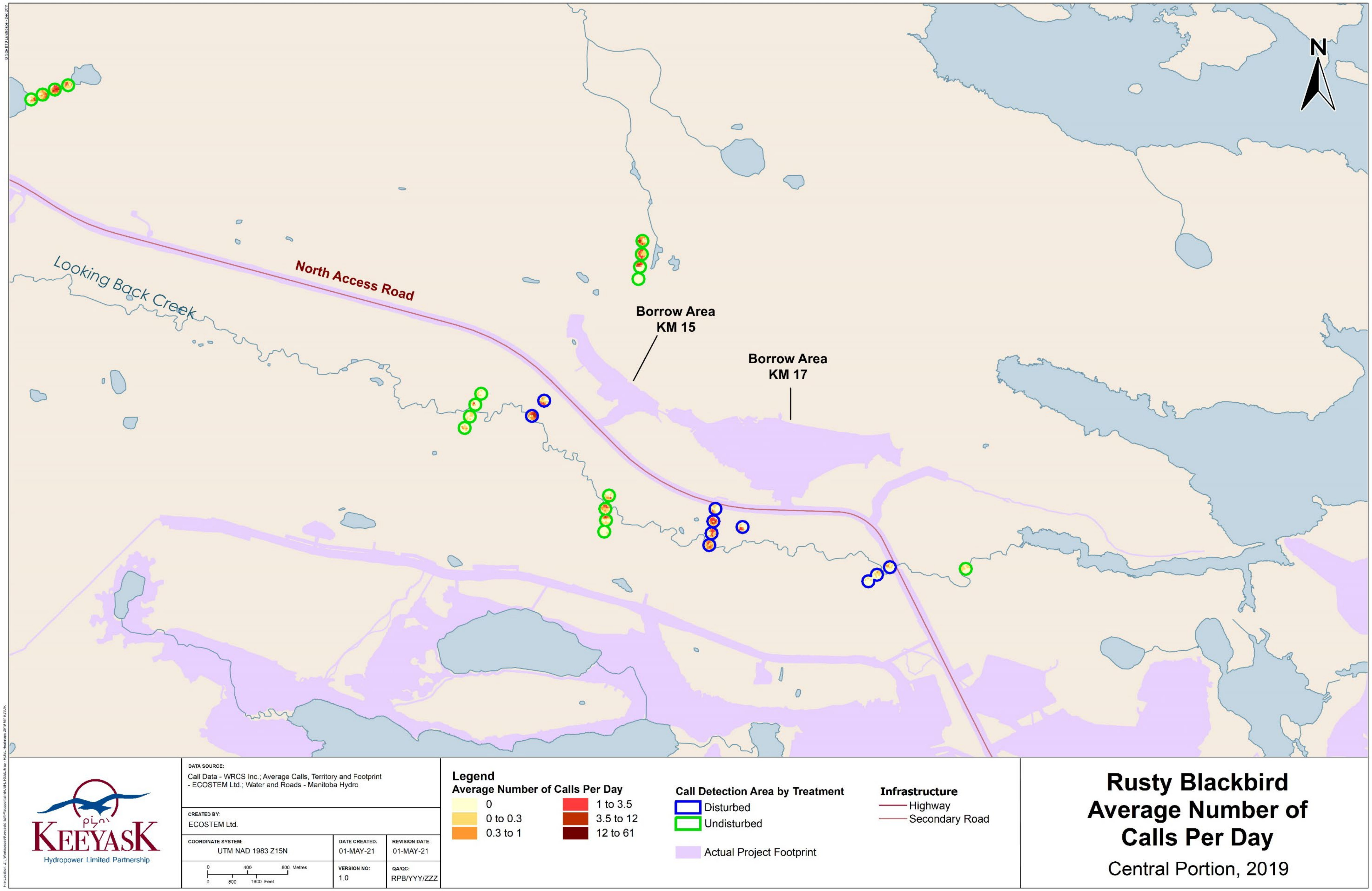
Map 3-6: Distribution of rusty blackbird in central listening areas in 2017



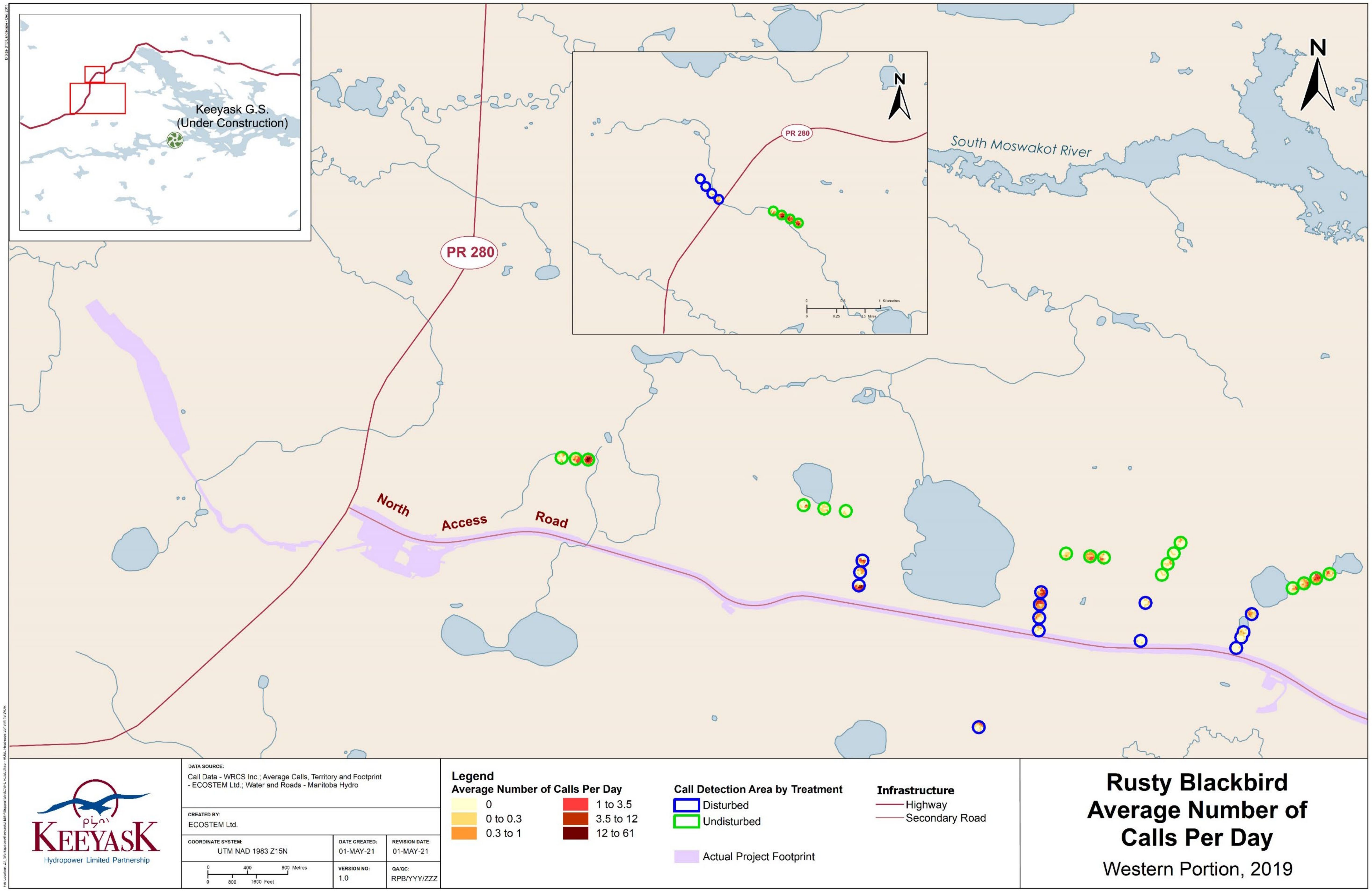
Map 3-7: Distribution of rusty blackbird in western listening areas in 2017



Map 3-8: Distribution of rusty blackbird in eastern listening areas in 2019



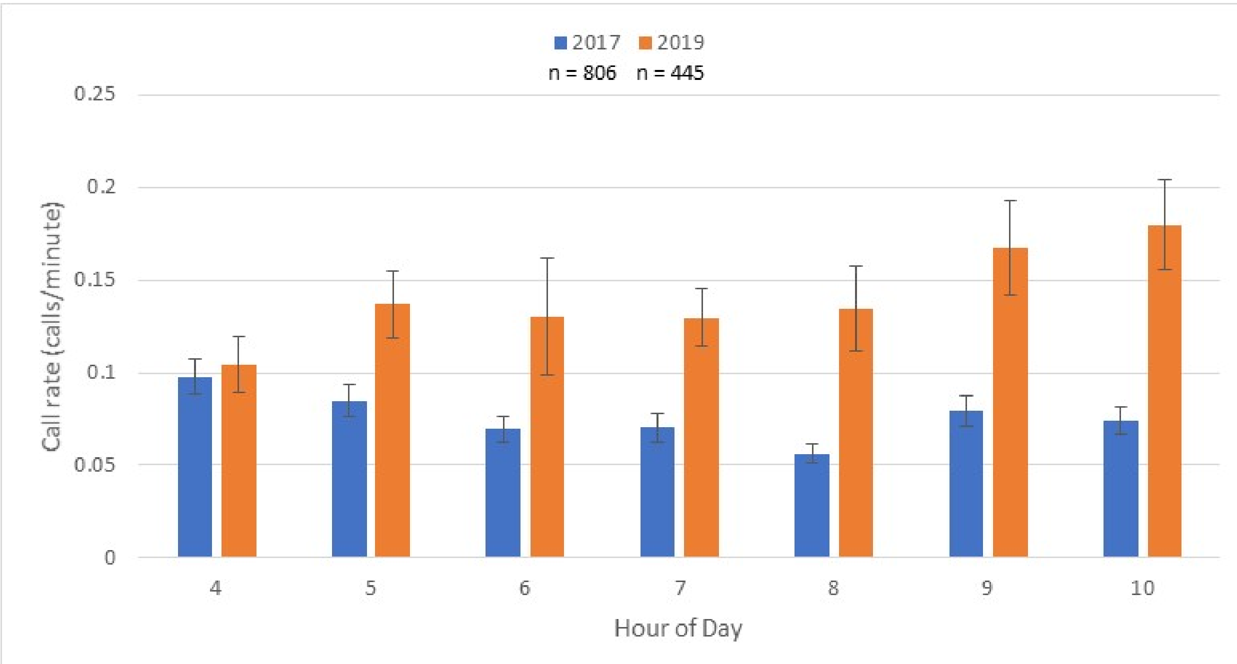
Map 3-9: **Distribution of rusty blackbird in central listening areas in 2019**



Map 3-10: Distribution of rusty blackbird in western listening areas in 2019

3.2.3 CALL RATES

The average call rate (calls/minute) for RUBL was variable over the morning on average (i.e., 4 AM to 11 AM; Figure 3-8), but there were no obvious increasing or decreasing trends with time. In 2017, the average call rate remained similar over the entire morning. In 2019, the call rate appeared to be highest between 9 AM and 11 AM. Future analysis will determine if this difference was statistically significant compared to the other hours.

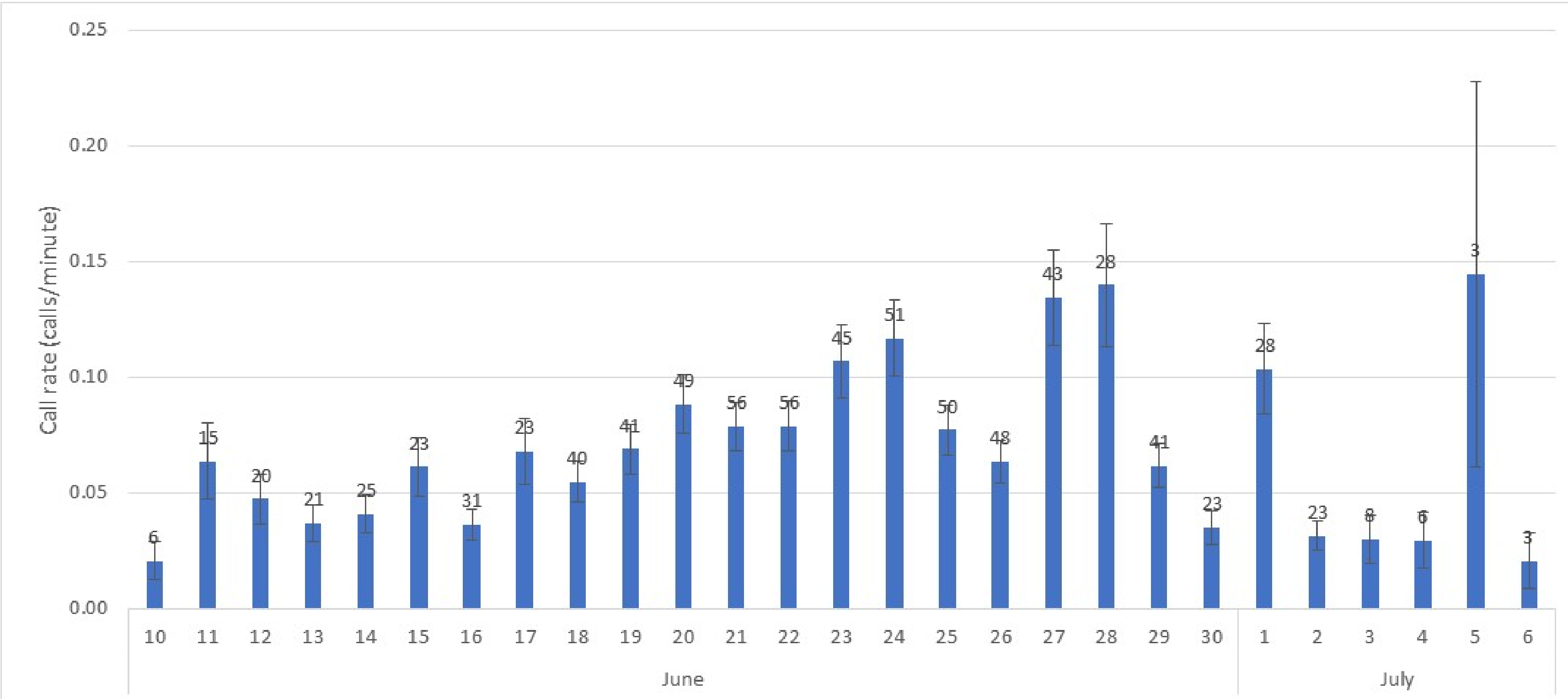


Notes: n = the number of recorders plus the cumulative number of recording days over the monitoring period.

Figure 3-8: Average call rate of RUBL by hour over the 2017 and 2019 monitoring periods. Error bars represent the standard error of the mean.

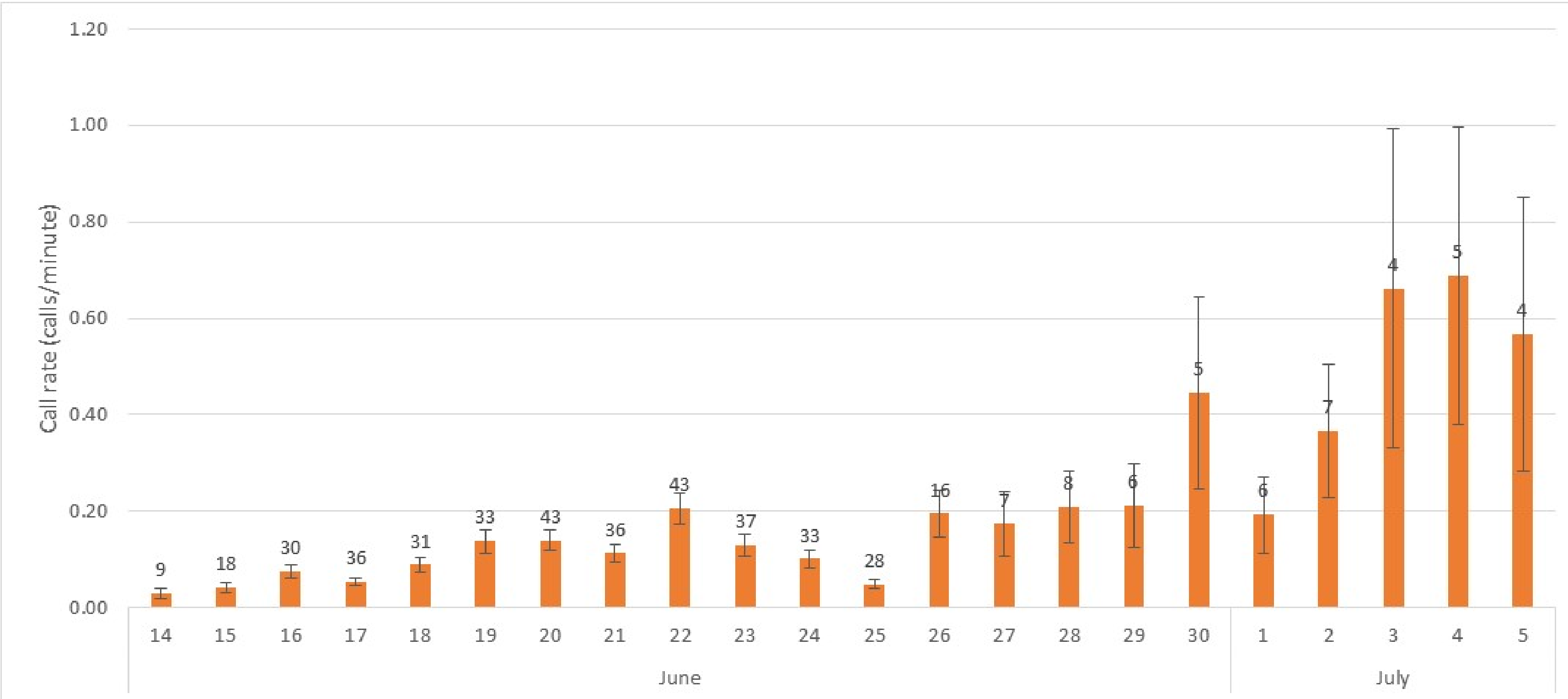
The day-to-day variation in the average daily call rate ranged by an order of magnitude over the monitoring period for 2017 (Figure 3-9). Average call rates over the day ranged from a minimum of 0.02 calls/minute (Julian days 161 and 187, or June 10 and July 6) to a maximum of 0.14 calls per minute (Julian days 179 and 186, or June 28 and July 5). In 2019, average call rates over the day ranged from a minimum of 0.03 calls/minute (Julian day 165, or June 14) to a maximum of 0.69 calls/minute (Julian day 185, or July 4; Figure 3-10).

Daily average call rates in 2017 did not show any trends or other patterns. In 2019, the average call rates appeared to increase starting on day 181 to the end of the survey period. Average call rates during this time were up to 3 times higher than earlier in the season and compared to the entire 2017 survey period.



Note: Numbers in error bars represent the number of recorders with call data on that day.

Figure 3-9: Average call rate of RUBL by day over the 2017 monitoring period. Error bars represent the standard error of the mean



Note: Numbers in error bars represent the number of recorders with call data on that day.

Figure 3-10: Average call rate of RUBL by day over the 2019 monitoring period. Error bars represent the standard error of the mean

4.0 DISCUSSION

Olive-sided flycatcher and rusty blackbird are species at risk and vulnerable to potential Project effects (WRCS 2018, 2020). The main objectives of these studies were to evaluate how sensory disturbances from the access roads influence olive-sided flycatcher and rusty blackbird distribution and relative abundance and to evaluate how Project-related sensory disturbance alters habitat effectiveness. To achieve the scientifically credible approach discussed in the TEMP for bird species at risk, a novel approach with automated recording units was used to generate the high-effort data requirements that were impossible to collect with human effort alone. Although there is precedent for using automated recording units for avian studies (Shonfield and Bayne 2017), it was necessary to estimate distance and direction to the vocalizing birds. Traditional methods that can acquire positional or movement data for wildlife usually involve trapping and radio-collaring animals. A non-invasive automated technique such as the one used in this study has not been used by the scientific community to monitor birds.

One of the novel aspects of this monitoring approach is that the recorders simultaneously captured sound in four directions, which enabled estimating the distance and direction of the bird relative to the recorder. The availability of these data enable relating bird call locations to the factors that influence bird habitat use, such as habitat quality and sensory disturbance. Other novel aspects of this monitoring included calibrated real-time clocks, which enabled a simultaneous capture of songs on two recorders, low power use so that lengthy field run-times could be achieved, and multiple power battery configurations so that the recorders could be used for different types of studies. All required features were not available on commercial products; as such, a custom design was necessary to meet the needs of this study.

Given the novel nature of this study, it was expected that technical difficulties would arise and require solutions. Despite the technical difficulties, a very considerable amount of bird call data were collected and processed (approximately 408,000 calls).

In all three survey years, individuals or breeding pairs for both OSFL and RUBL were successfully identified at many locations in the study area. Potential OSFL territories were identified and monitored at between 16 and 34 locations each year, and were found near the NAR and PR 280 all three years. There were fewer potential territories near the SAR; one was found in a disturbance area in 2016 and 2019 and none were found in 2017. Potential RUBL territories were identified at between 24 and 34 locations near all three sources of disturbance; however, three or fewer were found near the SAR each year.

This suggests that there is a well-established population for both bird species in the Project area. There was a high success rate in identifying areas that were utilized by both OSFL and RUBL, which is based on successful detection of the species by ARUs placed in those areas. For OSFL, between 94% and 100% of the listening areas established over the three survey years were utilized by OSFL to some degree, and between 89% and 100% were utilized by RUBL. The total number of calls detected by the ARUs over the three survey years ranged from 41,475 to 120,979 for OSFL, and from 9,535 to 13,316 for RUBL.

While there was no obvious indication that sensory disturbance from the Project access roads was reducing habitat effectiveness, there was no strong evidence that is was not. The listening areas for some territories had call voids adjacent to or near the access roads. However, some listening areas had high call rates adjacent to or crossing the access road.

To date, the multivariate analyses have focused on identifying possible technical issues with the call data and exploring the data to evaluate the best approach to standardizing call density.

Overall recorder effort varied across the three survey years for both OSFL and RUBL. In particular, average recorder effort was low in 2016, but was high in 2017 and 2019. The reason for the relatively low effort in 2016 was minor technical issues with the first generation ARUs during their first year of deployment.

The spatial distribution of call rates and the heat maps for OSFL and RUBL indicated a large degree of spatial variability in call density within the recorder listening areas. The most obvious partial, or perhaps complete, explanation for this finding is that it reflects a combination of natural variability in habitat quality and the locations of perch trees relative to territory boundaries. The validity of this will be examined through future analyses that will also consider the effects of sensory disturbance level (e.g., traffic volumes) and confounding factors such as partial data standardization, vegetation density and weather.

Based on the heat maps for OSFL, one of the nine undisturbed listening areas in 2017 had calls that appeared to overlap calls in a disturbed listening area. Classification of “disturbed” vs “undisturbed” listening areas in this report is based on the distance recorders were placed from the Project footprint (areas within 500 m of the footprint are considered “disturbed”). Automated recording units in undisturbed listening areas, but placed near the 500 m distance threshold, may detect calls occurring within the disturbed zone. Later analyses may reallocate such calls to the “disturbed” category, corresponding to their estimated distance from the Project footprint, as opposed to the position of the ARU that detected them.

Heat maps generally revealed one or more hot spots, or locations with particularly high activity in both the disturbed and undisturbed listening areas, which likely indicated preferred perching locations for the singing individual. Perch tree selection by OSFL is based primarily on tree species and height (Robertson 2012), while RUBL tends to select standing dead trees as perches (McNulty et al. 2015). All other things being equal, higher call rates and the number of hot spots within a listening area likely indicate areas of high-quality habitat for the species and suggests the presence of a breeding pair on-territory. Variations in activity relative to habitat quality will be examined through future analyses.

Some listening areas had multiple hot spots and very high average call rates. While this may reflect a high proportion of high-quality habitat for the species, it may also be indicative that confounding factors are present in the data. For OSFL, recording processing determined that the ARUs can detect calls greater than 300 m away from the unit. Typically, the ARUs were spaced approximately 200 m apart, resulting in approximately 100 m of overlap between the recorders. If an individual’s preferred perches occurred within this overlapping zone, it is likely that both recorders detected the call, resulting in double-counting.

Another potential confounding factor relates to the positional error inherent in the distance and direction estimator algorithm, which is caused by variability in terrain, weather, perch position and height, and direction of bird while singing. For this reason, each recorder may place the hot spot at a slightly different location in the listening area, giving the impression of two hot spots where there was actually one.

While double-counting may have influenced the heat maps to some extent (a hexagon may have included call locations from more than one recorder), the overall average call rates for each listening area were based on data from individual ARUs, and potential double-counting was not a factor. Looking at average call rates for the different listening areas, outliers with very high rates may be a stronger indication that birds from more than one breeding pair were detected in the listening area. As an example for OSFL, in 2017 the average number of calls per day for one listening area (P41 OSFL P) was nearly twice as much as the next highest area, and more than twice that of any area in 2019. Additional analyses will be implemented to determine if this listening area detected more than one breeding pair.

There were poorly defined hot spots, or few calls altogether, in some listening areas. While this may be indicative of poor habitat quality, it could also be under-utilized habitat. That is, the amount of suitable habitat may exceed what can be used by the local population. Several listening areas had either few or no recorded calls despite there being a confirmed presence of an individual at the time that the listening area was established in the field. Possible reasons for this finding include territory abandonment due to poor habitat quality, bird mortality, or the placement of recorders at the fringe of a potential breeding territory, or sensory disturbance. Because paired OSFL males with successful nests tend to reduce their singing rate and are less likely to be detected than unpaired males (Wright 1997), listening areas with fewer calls could also suggest a successfully mated male. Conversely, the presence of a perching bird during the initial site visit may not have been indicative of a nesting territory; a bird may have been perching in the area temporarily while searching for a territory or may have relocated part way through the breeding season (Wright 1997).

The daily pattern of call rates differed between OSFL and RUBL. OSFL showed a strong decreasing trend over the morning, with a very high call rate between 4 AM and 5 AM, then dropping substantially between 5 AM and 6 AM and decreasing gradually to 11 AM. This pattern supports the findings of other studies (e.g., Wright 1997) that indicate that calling frequency is highest in the hour surrounding sunrise, which occurs between approximately 4 AM and 5:15 AM during the survey period in the Keeyask region. In contrast, RUBL did not show a similar daily pattern. In 2017, call rates remained similar throughout the morning, and in 2019, they appeared to be higher between 10 AM and 11 AM compared to between 4 AM and 5 AM. An ARU study in Alberta indicated that RUBL were most likely to be detected early in the morning and that few were detected during the day (Nordell and Bayne 2017).

For both species, there appeared to be no obvious increasing or decreasing trends in call rate from earlier to later in the breeding season. In fact, the call rate varied substantially each day over the survey period. The one possible exception was for RUBL in 2019, where the average calls per day appeared to double starting on June 30. It is uncertain at this time if this represents a change in bird behaviour, or if it is an artifact of the subset of listening areas recording at this time. After June 26, the number of ARUs recording calls decreased, and the remaining ARUs may have been in areas that had higher call rates throughout the season. The day-to-day pattern in call rates was likely affected by a combination of other factors, such as weather conditions, or differences in ambient noise from day to day.

5.0 SUMMARY AND CONCLUSIONS

The recorder data provided considerable high-quality data for the study despite some technical difficulties. There was a large degree of spatial variability in OSFL and RUBL call density within the disturbed and undisturbed recorder listening areas. Some listening areas had multiple hot spots and very high average call rates, likely indicating preferred perching locations and suitable breeding habitat. Listening areas with poorly defined hot spots or few calls altogether may be indicative of poor habitat quality, under-utilized habitat that is suitable for breeding, males that have finished breeding and are rearing young, or reduced habitat effectiveness due to the degree of sensory disturbance. Confounding factors in the analysis of heat maps included potential double-counting, positional error inherent in the distance and direction estimator algorithm, vegetation density, variations in the level of sensory disturbance and recording more than one breeding pair in some listening areas. The forthcoming multivariate statistical and GIS analysis will incorporate the road disturbance, weather and habitat quality data to control for the factors that influence the OSFL and RUBL call rates.

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WRCS. 2020. Keeyask Generation Project Terrestrial Effects Monitoring Plan Report #TEMP-2020-15: Olive-sided Flycatcher and Rusty Blackbird Sensory Disturbance Monitoring

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APPENDIX 1:
BIRD AUDIO RECORDING ANALYSIS METHODS

Automated Recording Units (ARUs)

Although there is extensive precedent for using automated recording units (ARUs) for avian studies (Shonfield and Bayne 2017), we had difficulty finding an ARU to meet the needs of this study. In some of the species at risk studies proposed for the *Terrestrial Effects Monitoring Plan* (TEMP), for example, it was necessary to estimate distance and direction to the vocalizing birds. This required more than two channels of audio recording. Study design also demanded a large number of recorders to meet sample size requirements. After surveying the available technology, no recorders were found that could record four channels at a reasonable cost. Wildlife Resource Consulting Services MB Inc. commissioned Myrica Systems Inc. to design custom ARUs and a local contract assembler was hired to build them.

There were a number of criteria to be met in the ARU design:

- **Time accuracy**: ARUs contained a temperature-compensated quartz clock with an accuracy of +/- 2 minutes per year over a range of -40°C to 85°C.
- **Flexible time scheduling**: Timing parameters included start times, recording duration, interval, and number repetitions. Recordings can be corrected for sunrise and sunset over the season; units were loaded with daily sunrise and sunset times determined from National Oceanic and Atmospheric Administration (NOAA) calculations given the year, latitude, and longitude.
- **Lengthy unattended run time**: The design was optimized for minimal power consumption. ARUs could be powered from AA, D and 6V lantern batteries as required to meet recording time requirements.
- **Audio sensitivity**: Microphones were mounted in a separate case containing low-noise pre-amplifiers. Gain was set to match the sensitivity of human observers trained to identify bird calls.
- **Noise insensitivity**: Filtering was designed to remove frequencies above and below the range of interest for the bird species being recorded. This reduces, for example, wind noise. Microphones were also fitted with open-cell foam “windsocks”.
- **Environmental tolerance**: ARUs were designed and components chosen to operate in the full range of temperatures expected in the field. Microphone cables were sheathed in metal braid to resist chewing by rodents. Electronics were protected in weather proof cases.
- **Directionality**: Each of four microphones was mounted in a recessed hole on each face of a square enclosure. This provided a degree of audio isolation of each from its neighbours. The ‘north’ microphone was labelled on enclosures to permit alignment in the field.
- **Data storage**: ARUs were fitted with secure digital (SD) cards (8 gigabyte [GB] or 32GB) as appropriate for each study. The audio sampling rate was also varied to match study, storage, and analysis requirements (16.0 kilohertz [kHz] or 44.1 kHz). Files were compressed in Ogg Vorbis format (OGG) using a patent-and-royalty-free algorithm, which provided no noticeable signal degradation. Each field recording consisted of two stereo recordings on the SD card (A

and B). An audible time marker (click) was used to verify synchronization of the two stereo recordings.

- **Data identification**: Each ARU had a serial number label and was programmed with the same number in software. Recording file names contained the day of the year (DOY), hour (HH) and minute (MM) that the recording started. For example, two stereo recordings would be labelled 1832110A.ogg and 1832110B.ogg. As a back-up, data were embedded within the audio file that included time, date, and serial number.

Pre-processing Data

For each survey year, field recordings from each recorder were copied from SD cards into a directory structure on a hard drive matching the respective year, study, and site. Each recording for olive-sided flycatcher and rusty blackbird was 300 seconds in length. Data from each year comprised several terabytes despite data being in compressed format. Data were kept in separate working and backup repositories.

Analysis of bird vocalizations was performed using the statistical package R[1]. In order for data to be analyzed in R, OGG files had to be converted to wave (WAV) format using either SOX[2] or LameXP[3]. It was determined that an audio bandwidth of 5.5 kHz was sufficient to recognize the species of interest in recordings. For this reason, OGG files were converted to WAV format with a sampling rate of 11.025 kHz; this reduced the storage volume of uncompressed data and speeded file reading during analysis.

[1]R (www.r-project.org), a free statistical analysis software environment. The Package 'monitoR' (https://CRAN.R-project.org/package=monitoR) was used. monitoR is described briefly in "A short introduction to acoustic template matching with monitoR." Sasha D. Hafner and Jonathan Katz. February 14, 2018 (available from www.r-project.org) and in more detail in: "monitoR: Automation Tools For Landscape-scale Acoustic Monitoring - PhD Dissertation. Jonathan Katz. The University of Vermont. May, 2015.
[2]SOX (http://sox.sourceforge.net) is a free command line application for converting formats of and processing data in audio files.
[3] LameXP (http://lamexp.sourceforge.net) is a free audio file format converter with a windows front end.

Species Detection

Templates were created from exemplars of species vocalizations (calls) of interest. MonitoR uses a method called template matching to identify species by their sounds. The method can be thought of as taking a low-resolution spectrogram and measuring its correlation against the spectrogram of a whole recording. In fact, templates can be plotted as spectrograms.

It was necessary to use multiple exemplars for a given species to cover the range in variation of calls. It was also necessary to measure correlation against other non-target sounds (calls and environmental sound) that also had a high correlation with the same species.

Due to the very large collection of recordings for analysis, a balance needed to be struck between the detail of templates used and the speed of analysis; recording analysis with detailed templates would take much longer. Attention was also paid to the duration and frequency bandwidth chosen for each template. To reduce analysis time to a practical order of magnitude, a two-step process of analysis was required.

In the first step, a limited number of low-resolution templates were used to discover candidate calls of the target species, recognizing that there would be many false positives. These candidate calls were extracted as two-second sound clips with each clip starting one second prior to the centre of the call detection and running to one second after the centre of the call. Datasets were also created at this step that included clip file name and statistics about the candidate clip. A clip spectrogram was created for each clip that was useful for validation. By the second step, the volume of data had been greatly reduced and only clips were processed. These could then be analyzed at high resolution to remove most false positives.

Classification of clips involved setting a threshold for target and off-target calls and calculating a difference between the two. A viewing system for validation was developed to allow experts to view each call (clip) as a spectrogram along with its classification and to listen to it by simply clicking on the spectrogram. Summary statistics were created for all detections to aid in validation.

Distance and Direction Estimation

Sound pressure level in decibels (SPL), which humans perceive as ‘sound volume’, has been shown to provide a good estimate of distance to a calling bird (Yip et al. 2017). Direction can be estimated using the equivalent of Interaural Level Difference (ILD); from a human perspective this would be equivalent to using sound volume as a cue about direction (Nelson and Suthers 2004). Although many automated direction estimation algorithms use Interaural Time Difference (ITD), humans do not use this for high frequencies (Roman et al. 2003). There were several reasons why we were concerned that ITD might be unreliable in our studies. Some include: low signal to noise ratios (SNR), reverberation, environmental noise like wind, etc. In addition, our recording hardware was expected to have small differences that would be more pronounced at the high frequencies of bird calls. Microphones and circuits were identical by design, but tolerances in components were not and phase errors were expected. Exact synchronization of the two stereo recordings was problematic, even with the synchronization click that was used. We concluded that ILD was the best choice.

In order to calculate distance and direction to a singing bird recorded by the four-channel recorders, it was necessary to calibrate the system using bird songs recorded at varying distances. When a singing olive-sided flycatcher or rusty blackbird was observed, the observer would record the calls using the manual recording mode of the ARU. The distance of the bird from the observer was estimated using a rangefinder or waypoints taken at the observer's location and the bird's perch after it moved. Recordings were taken at approximately 20 m increasing increments until the bird could no longer be heard. Several dozen examples were collected using these techniques.

An algorithm was devised to find the peak root mean square (RMS) amplitude within each clip and convert it to a decibel value with an accurate time stamp. The four peak values were then used to triangulate the direction of the call; it was assumed that the calling bird was in the horizontal plane of the microphone array.

In the final data set, distance of the calling bird was estimated using decibel-distance curves created with field calibration recordings. Using the sound clips, distances were estimated by choosing the largest decibel value measured by the four microphones.

APPENDIX 2: SENSORY DISTURBANCE RECORDED ANALYSIS METHODS

Automated Recording Units (ARUs)

Equipment and parameters outlined in Appendix 1 were used.

Pre-processing Data

The same process and parameters outlined in Appendix 1 were used, with one exception. In this analysis OGG files were converted to WAV format with a sampling rate of 16 kHz yielding a maximum frequency of 8 kHz.

Data Analysis

For sensory disturbance analysis, directionality of sound was not considered important. For this reason, only the "B" recording was selected for analysis, and that recording was converted to monophonic. This greatly reduced computation time required. 300-second recordings were divided into 4-second segments for analysis.

Estimation of sensory disturbance potential using sound recordings has been done several times. One method involves examining the "loudness" of sounds (Buxton et al. 2020). Another method uses an index that discriminates between anthropogenic sounds and other environmental sounds. A commonly used index is the Normalized Difference Soundscape Index or NDSI (Kasten et al. 2012).

NDSI, as described in Doser et al. (2019), divides the audio spectrum into three regions. Region 1 (<1 kHz), geophonic sounds, are not considered as they likely come from sources like rain and wind. Frequencies in the range 1 kHz – 2 kHz (Region 2) are considered to be of anthropogenic origin. Frequencies above 2 kHz (Region 3) are considered biological sounds. NDSI values near one are considered to be from biological sources while values near minus one are considered to be of anthropogenic origin. Several studies indicated the utility of NDSI (Fairbrass et al. 2017; Turner et al. 2020; Samuel et al. 2021)

In this analysis we calculated NDSI for each 4 second segment using the Soundecology package in R. Parameters used were: fft_w = 1024, anthro_min = 1000 Hz, anthro_max = 2000 Hz, bio_min = 2000 Hz and bio_max = 8000 Hz.

To estimate "loudness", we calculated the RMS in R for sounds in three frequency ranges. Power Spectral Density (PSD) was calculated for each segment for the range 0 Hz – 8kHz. RMS was calculated for 0 Hz – 8kHz and the three ranges described above. Values were log transformed ($20 * \log_{10}(RMS + 1) – 100$) due to the large range to yield a value analogous to an audio decibel value with a the loudest values being near zero. Since microphones were not calibrated against a standard, these values yield relative loudness usable for comparisons within the study.

A data record was created for each 4-second segment with date, time, location, NDSI and RMS values.