Columbia River Project Water Use Plan

KINBASKET AND ARROW LAKES RESERVOIRS

Reference: CLBMON-39 & CLBMON-11B2

Arrow Lakes Reservoir: Neotropical Migrant Use of the Drawdown Zone

Arrow Lakes Reservoir: Revelstoke Reach Spring Songbird Effectiveness Monitoring

Study Period: 10 Year Final Report, 2008-2017

Hemmera Envirochem Inc.

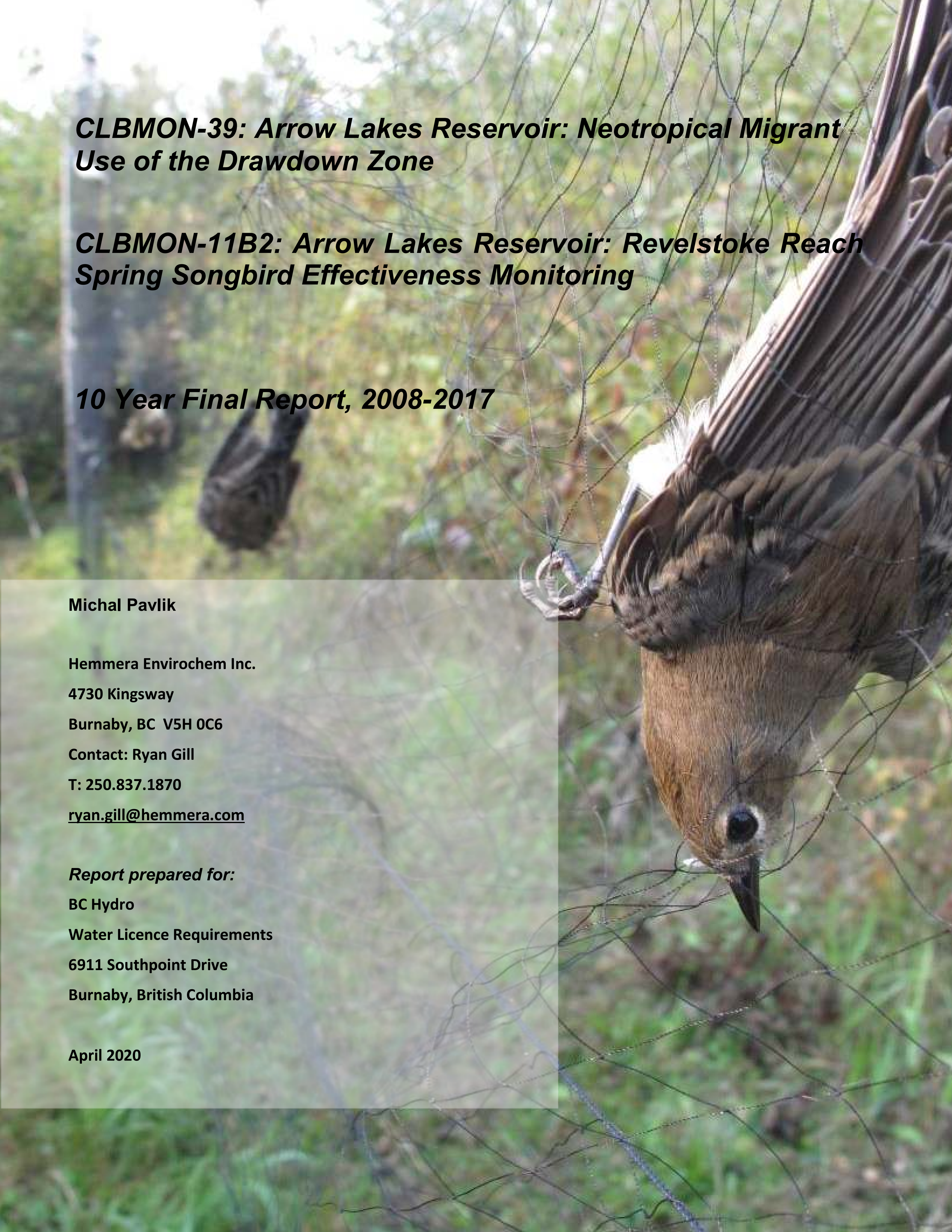
18th Floor, 4730 Kingsway

Burnaby, BC V5H 0C6

T: 604.669.0424

F: 604.669.0430

April 2020



CLBMON-39: Arrow Lakes Reservoir: Neotropical Migrant Use of the Drawdown Zone

CLBMON-11B2: Arrow Lakes Reservoir: Revelstoke Reach Spring Songbird Effectiveness Monitoring

10 Year Final Report, 2008-2017

Michal Pavlik

Hemmera Envirochem Inc.

4730 Kingsway

Burnaby, BC V5H 0C6

Contact: Ryan Gill

T: 250.837.1870

ryan.gill@hemmera.com

Report prepared for:

BC Hydro

Water Licence Requirements

6911 Southpoint Drive

Burnaby, British Columbia

April 2020

Suggested Citation:

Pavlik, M. 2020. CLBMON-39: Arrow Lakes Reservoir Neotropical Migrant Use of the Drawdown Zone & CLBMON-11B2: Arrow Lakes Reservoir Revelstoke Reach Spring Songbird Effectiveness Monitoring, Year 10 Final Report, 2008-2017. Unpublished report by Hemmera Envirochem Inc., Burnaby, BC, for BC Hydro Generation, Water Licence Requirements, Burnaby, BC 39 pp. + apps.

Cover photo: Yellow-rumped Warbler (*Setophaga coronata*) in a mist net at Machete Island banding station, Revelstoke Reach, 2017. Photo: Michal Pavlik

Hemmera
An Ausenco Company

syilx
Okanagan Nation Alliance

EXECUTIVE SUMMARY

This report summarizes findings from two related multi-year studies of neotropical migrant songbirds in the drawdown zone of the Arrow Lakes Reservoir. In the study area, valley bottom habitat was limited due to serial reservoir impoundments along the Columbia Valley, and habitats within the reservoir drawdown zone may have significance for migrant birds, especially as stop-over habitat where migrating birds can put on fat to fuel their migration. During spring migration, the reservoir was reliably drawn down to low levels providing a wide variety of exposed habitats within the reservoir's drawdown zone. During the fall migration, the reservoir elevations differed greatly among years, allowing variable availability of habitat within the drawdown zone.

CLBMON-39 was a 10-year (2008 to 2017) monitoring program designed to determine the effects of reservoir operations on fall neotropical migrant songbirds in Revelstoke Reach of Arrow Lakes Reservoir near Revelstoke, BC. Field studies were conducted annually and included constant-effort mist netting, permanent and random plot surveys for songbird use, effectiveness monitoring of wildlife physical works and revegetation treatments, assessment of fall migrant fattening rates based on plasma metabolites, and habitat assessments.

CLBMON-11B2 was a 9-year (2009 to 2017) monitoring program that monitored habitat use by neotropical migrant songbirds during the spring migration in the same study area as CLBMON-39. Field studies were conducted in most years (2009 to 2014, 2016) and included permanent and random plot surveys for songbird use, effectiveness monitoring of wildlife physical works and revegetation treatments, encounter transects, and habitat assessments.

During fall surveys, 73 species and more than 37,000 records of neotropical migrants were documented during the study with abundance peaking in late August and species richness peaking in mid-August. Eleven species, mainly warblers and flycatchers, accounted for the majority of migrants with Common Yellowthroat (*Geothlypis trichas*) accounting for 21% of all fall migrants captured in constant effort mist netting. There was variation in abundance between years with Yellow-rumped Warbler (*Setophaga coronata*) showing the highest annual variability.

In spring, 65 species and more than 10,000 records were documented during the study. The most abundant spring migrant species were quite different from the most abundant fall migrants. American Pipit (*Anthus rubescens*) was the most abundant spring migrant species but was almost absent in fall. Only two warbler species were in the top 12 spring migrants. Differences in migration timing, study timing, and habitat availability elsewhere likely account for much of the differences in species abundances between seasons.

Broad habitat-use by migrants was highly stratified with abundance and species richness of both fall and spring migrants highest in forest, followed in descending order by shrub, grassland, and unvegetated habitats. At a finer scale, fall migrants had the highest abundance and species richness in well-developed riparian habitat (riparian forest, riparian shrub) and complex wetland habitat (swamp, cattail, wet meadow). In general, fall migrant abundance increased with increasing shrub and forest cover on plots and species richness increased with increasing forest and shrub cover and decreasing herbaceous cover on plot. The presence of wood-warblers on plots was positively affected by percent of shrub cover and the presence of sparrows and Common Yellowthroat on plots was positively affected by percent of herbaceous cover and negatively by percent of tree cover.

Spring migrants had the highest abundance and species richness in forested habitats (upland forest and riparian forest), well-vegetated wetland habitats (swamp, cattail), and shrub savannah. In spring, wood-warblers and flycatchers reached the highest abundance in forest plots, sparrows in shrub plots, and American Pipit in grassland and unvegetated plots.

To assess effects of reservoir operations on fall neotropical migrant physiology, plasma metabolite samples from six species were assessed to determine fattening rates. No consistent effect of reservoir water levels (among years with different reservoir operations or among sites

with different flooding frequencies) on fattening rates was documented suggesting that reservoir operations do not significantly impact fattening rates of neotropical migrants in shrub and forest habitat in Revelstoke Reach during fall migration.

A wide range of peak summer reservoir levels were experienced during the study. As expected, reservoir operations impacted quantity of fall migrant stopover habitat available as, for example, 79% of drawdown zone area was flooded when reservoir elevation reached 438 m above sea level, but effects were largely mitigated by the relatively low use of habitats below that elevation (unvegetated, grassland, wetland, low shrub) and the ability of most species to move to higher elevation shrub and forested habitats. These results, and the results of the plasma metabolite study, demonstrate that reservoir operations, observed during the study period, have no significant effect on quality of stopover habitat for most fall migrants, except for those few species that are obligate grassland users.

Reservoir operations affected use of certain habitats by fall migrants on permanent plots monitored annually, with increasing water depth having a negative effect on use of grassland and shrub habitats, but no significant effect on use of forest habitat. Use of grasslands was essentially precluded when flooded, but this impact affected a relatively small number of individual songbirds and species because grassland-obligate species were uncommon during the fall migration. Reservoir operations had no effect on overall abundance or species richness as measured at intensively studied banding stations in shrub or forested habitat but had a small effect on species richness in lower elevation shrub habitat.

Reservoir operations had limited effects on spring migrant habitat and, therefore, on spring migrants, until late in the spring migration (late May) when reservoir levels began to inundate grasslands. Even then, effects on use of the drawdown zone were minimal as there were relatively few grassland-using spring migrants present in the drawdown zone by late May.

There was no consistent increase in utilization of areas revegetated with cottonwood stakes by spring or fall migrants over time. Higher abundance and species richness were expected given that shrub habitats have higher use than grasslands, but effects were limited by poor survival of stakes at some sites and the relatively short period of time for growth of the stakes. Use is expected to increase as the surviving stakes mature into larger shrubs and trees. The planting of cottonwood stakes has the potential to improve habitat use in current grasslands, but large areas would need to be planted and sufficient time allowed for regrowth before plantings would have a notable effect on migrant populations.

Areas planted with sedge were monitored for spring migrants for two years, then discontinued as the area was too small, planted sedge merged with natural sedge so as to be indistinguishable, and sedge cover is an unsuitable habitat for most neotropical migrants.

No wildlife physical works projects were implemented during the study that directly benefited neotropical migrants, but potential exists to protect or enhance forest and shrub habitats, although effects on other life stages of neotropical migrants or other wildlife species would need to be assessed.

Review of findings from 10 years of fall migrant monitoring under the CLBMON-39 program.

<table>
<tr><th>Management Question</th><th>Summary of Key Monitoring Results</th></tr>
<tr><td>MQ-1 What is the seasonal and annual variation in the abundance and species richness of neotropical migrants in Revelstoke Reach during fall migration?</td><td>FALL
Seasonal and annual variation was well characterized by the data for all common migrants during the fall migration, especially in riparian forest habitat (Machete Island).
73 species of neotropical migrants recorded.
Abundance of migrants varied throughout the season, peaking in late August.
Species richness varied throughout the season, peaking in mid-August.
Abundance of migrants, but not species richness, varied among years.
Common Yellowthroat was the most common migrant; abundance peaked in late August to early September.
SPRING
Seasonal and annual variation was well documented.
65 species of neotropical migrants recorded.
America Pipit was the most abundance migrant.
Notable differences in the detected species and their abundances when compared to fall migration monitoring. Some of the most frequently recorded species during spring migration (e.g., American Pipit, American Robin, swallows, Chipping or White-crowned Sparrow) did not rank among the most abundant during fall migration and common species during fall migration (e.g., Traill’s Flycatcher, American Redstart, Swainson’s Thrush, Red-eyed Vireo) were recorded in spring only in low numbers.</td></tr>
<tr><td>MQ-2 Which habitats within the drawdown zone in Revelstoke Reach are utilized by neotropical migrants and what are their characteristics?</td><td>FALL
Abundance and species richness of fall migrants was the highest in forest plots, followed by shrub plots, grassland plots, and unvegetated plots.
On a finer scale, abundance and species richness was the highest in riparian habitats (riparian forest, riparian shrub) and complex wetland habitats (swamp, wet meadow, cattail).
Wood-warblers and flycatchers were most abundant on forest plots
Sparrows and Common Yellowthroat were most abundant on shrub plots.
Abundance and species richness of migrants was positively affected by increasing tree and shrub cover on plots.
Species richness was negatively affected by increasing herbaceous cover on plot.
Presence of wood-warblers on plots was positively affected by increasing shrub cover, and presence of sparrows and Common Yellowthroat was positively affected by herbaceous cover and negatively affected by tree cover on plots.
SPRING
Abundance and species richness of spring migrants was the highest in forest plots, followed by shrub plots, grassland plots, and unvegetated plots.
On a finer scale, abundance and species was the highest in forested habitat (upland forest and riparian forest) and complex wetland habitat (swamp, cattail).
In spring, wood-warblers and flycatchers were most abundant on forest plots, sparrows on shrub plots, and American Pipit on grassland and unvegetated plots.</td></tr>
</table>

Management Question	Summary of Key Monitoring Results
MQ-3 Do reservoir operations influence the species richness or abundance of neotropical migrants using habitat in the drawdown zone during fall migration? If so, how do reservoir operations influence the species richness or abundance?	• Presence of neotropical migrants on grassland and shrub plots decreased with increasing water depth on plot. There was no significant effect of water depth on the presence of migrants on forest plots. • At the station higher in the drawdown zone (Machete Island), there was no effect of daily water levels (at the site) on daily capture rate or daily species richness. • At the station lower in the drawdown zone (Airport Islands) daily species richness, but not daily capture rate, tended to be negatively affected by the daily water level at the site. • No consistent effect of reservoir operations (maximum annual water level, reservoir water level on Aug 7, or number of days from Jan to Sep with a water level over 438 m ASL) on neotropical migrant abundance (overall annual capture rates) was documented contrasting two sites in the drawdown zone with the site outside of the drawdown zone. • Lower elevation habitats are more likely to be negatively affected by reservoir operations; however, these habitats are also used less intensively by migrants. • While reservoir operations influenced the spatial distribution and the use of different habitats by migrants, there is minimal indication that reservoir operations observed during the study period significantly influenced overall neotropical migrant abundance or species richness in the drawdown zone.
MQ-4 Which neotropical migrants are most affected by reservoir operations?	• Species most affected by reservoir operations are species that prefer open grassland or unvegetated habitat (which is positioned lower in the drawdown zone). • These include several species of sparrow that use grasslands (especially Savannah Sparrow, but to a lesser extent also Lincoln's Sparrow), Common Yellowthroat (the most common fall migrant), American Pipit, and Western Meadowlark.
MQ-5 Do reservoir operations affect the fattening rates of neotropical migrants using the drawdown zone during fall migration?	• No significant differences in estimated fattening rates for any species were found either among stations with different flooding frequencies or among years with different reservoir operations. • Reservoir operations do not significantly impact fattening rates of neotropical migrants in shrub and forest habitat in Revelstoke Reach during fall migration.
MQ-6 Can operational adjustments be made to reduce impacts on neotropical migrants during fall migration or are mitigation measures required to minimize the loss of stopover habitat?	• Operational adjustments or mitigation measures that could benefit neotropical migrants during fall migration could not be identified by this study.
MQ-7 *Original question 7 deleted (as per updated ToR)*	
MQ-8 Are the ongoing revegetation projects effective at improving utilization of the treated habitat in the drawdown zone by neotropical migrants?	• At the 12 Mile area, the site with the best growth of cottonwood stakes, no increase in abundance or species richness of neotropical migrants was observed. • Overall there was no consistent change in abundance or species richness on treatment plots over time (2011 to 2016). • However, since abundance and species richness of migrants is higher in forest or shrub habitats, the cottonwood stake plantings seem to have potential for enhancing migrant bird habitat if sufficient time is allowed for their regrowth.

Management Question	Summary of Key Monitoring Results
MQ-9 Does the operation of Arrow Lakes Reservoir impact the availability or quality of stopover habitat in Revelstoke Reach for neotropical migrants?	• Reservoir operations impacted the quantity of stopover habitat available for certain fall migrant species. • When water levels were at 438 m ASL, most forested habitats remained unflooded, approximately 50% of shrub habitat was flooded and most of the grassland habitat was flooded. • Overall, 79% of all available drawdown zone habitat was flooded when reservoir elevation reached 438 m ASL, but biologically, this effect was negligible due to the poor suitability and low use of low elevation habitats inundated (unvegetated, grassland, wetland, low shrub). • Results of the plasma metabolite study concluded that reservoir operations do not affect fattening rates of migrants at the upper elevation habitats that are most suitable. This suggests that reservoir operations have no significant effect on quality of stopover habitat for most fall migrants, except for those few species that are obligate grassland users.

Review of findings from spring migrant monitoring under the CLBMON-11B2 program.

Management Question	Summary of Key Monitoring Results
MQ-11B2-1 Are the revegetation and the wildlife physical works projects effective at enhancing wildlife habitat in the drawdown zone?	• No consistent increase in abundance or species richness was observed on treatment plots over time (2010 to 2016). • No evidence that cottonwood stake planting improved neotropical migrant use of the treated areas over the course of this study. • However, the cottonwood stake plantings seemed to have potential for enhancing migrant bird habitat if sufficient time is allowed for regrowth.
MQ-11B2-2 If revegetation and the wildlife physical works projects enhance wildlife habitat in the drawdown zone, to what extent does the revegetation program and the wildlife physical works projects increase the productivity of habitat in the drawdown zone for wildlife?	• This Management Question has no relevance to this module of CLBMON-11B program. Module 2 did not consider habitat productivity.
MQ-11B-3 Are some methods or techniques more effective than others at enhancing wildlife habitat in the drawdown zone?	• Of all revegetation treatments and wildlife physical works projects conducted during the timeframe of this project, revegetation with cottonwood stakes and other deciduous saplings is probably the most beneficial to neotropical migrants.

KEYWORDS

Reservoir operations, neotropical migrants, songbirds, fall migration, spring migration, stopover habitat, plasma metabolites, fattening rates, Arrow Lakes Reservoir, British Columbia, BC Hydro

ACKNOWLEDGEMENTS

Many people have contributed greatly to completion of the CLBMON-39 and CLBMON-11B2 projects. BC Hydro WLR sponsored the projects. Over the ten years of these projects, guidance and support were provided by many BC Hydro staff members, including Doug Adama, Margo Sadler, Evy Grouwstra, Ed Hill, Trish Joyce, Harry van Oort, Susan Pinkus, Ian Robertson, and Jason Watson.

During 2008 to 2017, field studies were completed by many Cooper Beauchesne and Associates Ltd. (CBA) field staff (Devon Anderson, Rudy Badia, Corey Bird, Pierre-Paul Bitton, James Bradley, Russell Cannings, Stacey Carnochan, Catherine Craig, Kate England, Jason Fidorra, Ryan Gill, Jennifer Greenwood, Peter LeCouffe, Paul Levesque, Janice Jarvis, Harry van Oort, Michal Pavlik, Lucie Parker, Jeannine Randall, Emily Smith, and Emily Williams), and CBA Interns (Sylvia Neufeld and Laurenz Teubert).

Michal Pavlik planned the 2009 to 2017 field study program and acted as bander-in-charge. Ryan Gill provided GIS mapping and analysis. Suzanne Beauchesne provided overall supervision and monitoring of crews. John Cooper acted as Project Manager.

From 2014 to 2017, CBA collaborated with the Okanagan Nation Alliance (ONA) for delivery of CLBMON-39, with ONA biologists and technicians providing field and technical support, and insight into the perspectives and protocols of the Syilx (Okanagan) people. Mike Dunn, Alexis Friesen, Autumn Solomon, Bruce Weaver, Kayla Williams, and Karle Zelmer of the ONA contributed to field studies. Al Peatt and Dave DeRosa managed the ONA’s involvement.

CBA also collaborated with Simon Fraser University (SFU). Dr. Tony Williams graciously provided his graduate student Dominique Wagner. SFU staff (Margaret Eng, Christine Rock, Marc Travers and Dominique Wagner) contributed to field studies. Dominique Wagner, Dr. David Green and Dr. Tony Williams of SFU processed collected blood samples and conducted the plasma metabolite analyses.

Lesley-Anne Howes and Louise Laurin (Environment Canada Bird Banding Office) processed scientific permits to capture and band birds and to collect blood and feather samples.

CBA would also like to thank the community of Revelstoke for providing a safe and enjoyable home base for field crews during the duration of the Projects.

All data collection and annual reporting from 2008 to 2017 was completed by CBA and an initial draft of this report was submitted by CBA in November 2018. Additional data analysis and revisions to this report were completed by Hemmera Envirochem Inc.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1 INTRODUCTION

Since the late 1980s, neotropical migrant birds have become a focus of wildlife managers due to population declines and threats to habitats in their breeding and wintering ranges (Terborgh 1989, DeSante and George 1994, Martin and Finch 1995, Sherry and Holmes 1996). More recently, migratory stopover habitat has been highlighted as a significant conservation concern as critical riparian habitat is in serious decline throughout North America (Martin et al. 2007, Carlisle et al 2009). Neotropical migrant birds include more than 200 species that generally breed north of the Tropic of Cancer, and at least 5% of the population winters south of that latitude (U.S. Fish & Wildlife Service 2011). This group of birds is comprised mainly of songbirds but it also includes some species of waterfowl, raptors, gulls, terns, shorebirds, hummingbirds, swifts and others (DeGraaf and Rappole 1995). CLBMON-39 and CLBMON-11B2 focus on neotropical migrant songbirds.

During Water Use Planning for the Columbia River, the Consultative Committee recognized that the upper portion of Revelstoke Reach of the Arrow Lakes Reservoir (ALR) provides high quality habitat for breeding and migratory birds (Tremblay 1993, AXYS 2002, Boulanger et al. 2002, Jarvis and Woods 2002, MCA 2003, Boulanger 2005, Green and Quinlan 2007). The Consultative Committee then recommended that monitoring be conducted to determine how variation in reservoir levels and the implementation of soft constraints affects the abundance and habitat use of neotropical migrant songbirds in Revelstoke Reach during fall migration (BC Hydro 2007). The soft constraint developed for ALR relevant to songbird fall migration was to:

> *ensure that the availability of migratory bird habitat in the fall is as good as or better than that which has been provided on average over recent history (1984–1999). Draft the reservoir quickly after full pool (defined as 440.1 m under the Columbia River Treaty) is reached, targeting a reservoir level of 438 m or lower by August 7*.

CLBMON-39 (Arrow Lakes Reservoir: Neotropical Migrant Use of the Drawdown Zone monitoring program) is a 10-year wildlife monitoring program initiated by BC Hydro in 2008.

CLBMON-11B2 was initiated as a component of CLBMON-11B in 2009 and focussed on the monitoring of spring migrant neotropical migrant songbirds in relation to the effectiveness of revegetation and wildlife physical works (WPW) projects in Revelstoke Reach. CLBMON-11B2 was incorporated into CLBMON-39 from 2012-2017 although field studies were not conducted every year during that period.

This report completes both CLBMON-39 and CLBMON-11B2, hereafter collectively referenced as the Project(s). The report uses all available data to address eight Management Questions for CLBMON-39 and three Management Questions for CLBMON-11B2.

1.1 Objectives of CLBMON-39

CLBMON-39 was specifically designed to:

1) Determine the migration patterns of neotropical migrants in Revelstoke Reach over time (within season, across seasons, and across years).
2) Assess whether reservoir operations affect populations of neotropical migrants that use the area as a stopover site.
    a) Examine the effects of reservoir operation on the abundance, diversity, habitat availability, and fattening rate of neotropical migrants in Revelstoke Reach.
    b) Identify species that have a higher likelihood of being affected by reservoir operations.
3) Determine whether there are specific times during the migratory season when minor adjustments to flow rates or water levels will enhance the ability of the drawdown area to support neotropical migrants.

4) Provide information with respect to how wildlife physical works or revegetation can increase utilization of treated riparian habitat by neotropical migrants.

5) Determine habitat use by neotropical migrants in the drawdown zone of Revelstoke Reach over time (within season, across seasons, and across years) and the impacts of reservoir operations on habitat availability and quality.

1.2 Objectives of CLBMON-11B2

The objectives of CLBMON-11B2 were to:

1) Conduct a monitoring program to assess the effectiveness of the revegetation physical works program and wildlife physical works projects at enhancing wildlife habitat in the drawdown zone of Arrow Lakes Reservoir.

2) Monitor the appropriate biological indicators and response variables to assess the effectiveness of the revegetation and wildlife physical works programs at enhancing wildlife habitat in the drawdown zone.

3) Provide recommendations on the effectiveness of the revegetation and wildlife physical works projects on improving habitat for wildlife in the drawdown zone.

The Projects were designed to provide information that will support future decisions about how to manage the operating regime of the ALR and/or improve habitat condition in the drawdown zone to protect neotropical migrant songbird habitat and populations during migration. BC Hydro provided specific Management Questions to be addressed at the completion of CLBMON-39 and CLBMON-11B2. Associated management hypotheses are provided in **Error! Reference source not found.** (CLBMON-39) and **Error! Reference source not found.** (CLBMON-11B2).

2 STUDY AREA AND RESERVOIR OPERATIONS

The study area for the Projects was defined as the drawdown zone of Revelstoke Reach. Revelstoke Reach is the northernmost arm of the ALR south of Revelstoke, BC, and is located between the Monashee and Selkirk Mountains (Figure 1).

This hydroelectric reservoir, regulated by the Hugh Keenleyside Dam near Castlegar, BC, is licensed to operate between 418.6 m and 440.1 m elevation under constraints imposed by the Columbia River Treaty (BC Hydro 2007). The drawdown zone is defined as the area between these reservoir elevation extremes.

Revelstoke Reach lies within the Interior Cedar Hemlock (ICH) biogeoclimatic zone and consists of two subzones (ICHmw2 and ICHmw3) (Meidinger and Pojar 1991). The valley bottom habitats in the area were naturally vegetated with old-growth stands dominated by western redcedar (*Thuja plicata*), Englemann spruce (*Picea engelmannii*), and black cottonwood (*Populus balsamifera* ssp. *trichocarpa*). Prior to dam completion in 1968, the Revelstoke Reach area also contained productive farmlands.

The present day vegetation of the Revelstoke Reach drawdown zone is influenced mostly by elevation (Korman 2002), which reflects the timing and extent of annual flooding. The lowest elevation drawdown habitats (below 433 m) are unvegetated. Above 433 m, the Revelstoke Reach drawdown zone is vegetated extensively by reed canary grass (*Phalaris arundinacea*) and sedges (*Carex* spp.), with several other species of graminoids and forbs established locally (Moody 2002). Above 436 m, willow shrubs (typically *Salix sitchensis*) have become established both naturally and as a result of previous planting efforts. At the lower extent of their distribution in the drawdown zone (around 436 m), willows usually grow as sparsely distributed solitary shrubs, but above 437 m they commonly grow in dense clusters of varying sizes. Cottonwood saplings and other species of willow (e.g., *Salix scouleriana*) are abundant in many of these patches. Near the full pool elevation (439 m to 440 m), some patches of mature cottonwood riparian habitat occur, but this habitat type is uncommon throughout the Revelstoke Reach drawdown zone. In these patches, black cottonwood is usually a dominant canopy species, and there can be a diversity of other tree and shrub species.

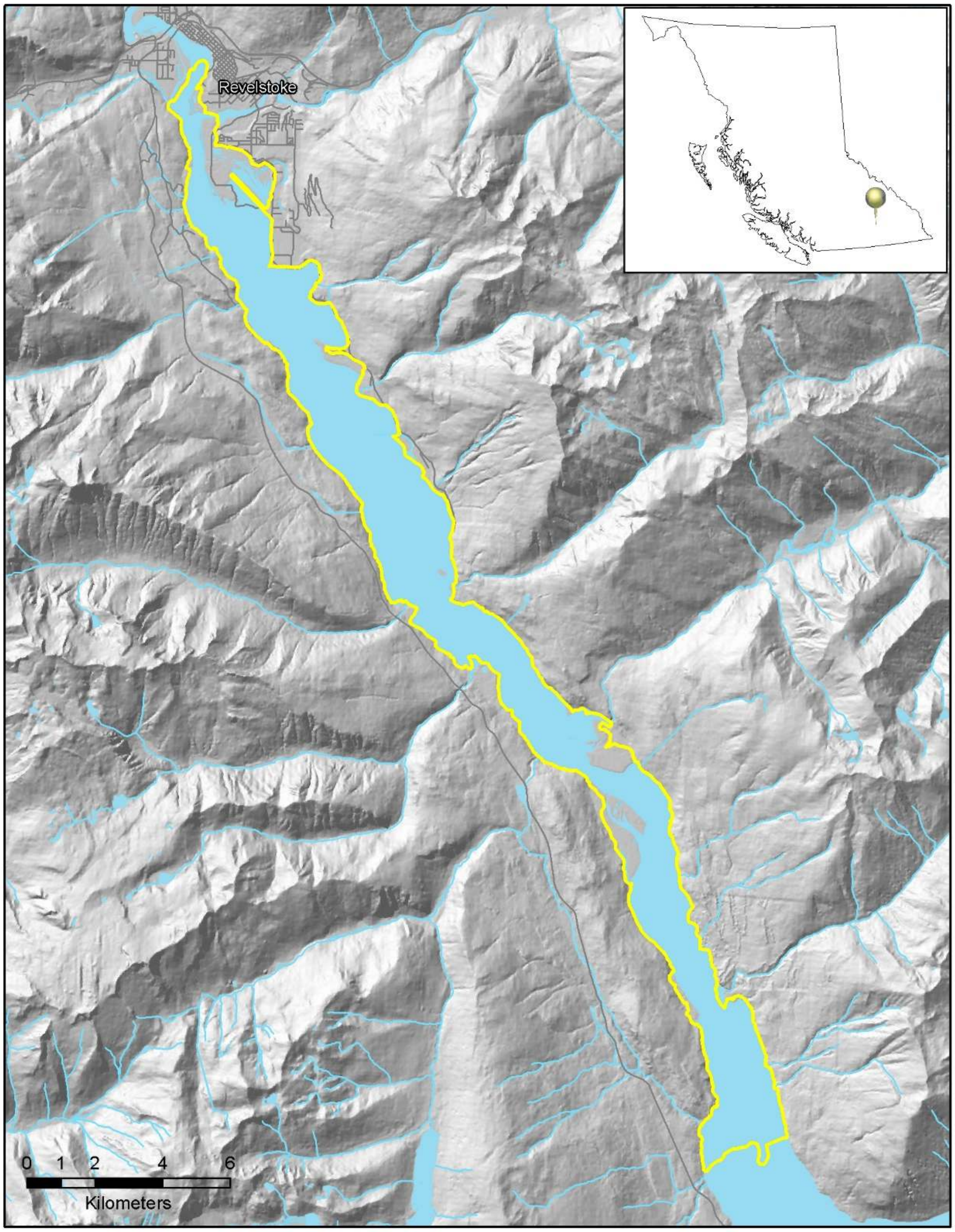


Figure 1: CLBMON-39 and CLBMON-11B2 study area in Revelstoke Reach, Arrow Lakes Reservoir. Yellow outline delineates Revelstoke Reach.

2.1 Overview of Reservoir Operations from 2008 to 2017

The reservoir is typically operated to store water in spring and summer, and occasionally into the fall, and to release water through Keenleyside Dam during the winter months, creating a cyclical annual pattern of reservoir elevations. During the ten years of this study, three years (2009, 2015, and 2016) can be classified as “dry years” in which none of the high-quality stopover habitat above 438 m was inundated in summer. Another three years (2010, 2013, and 2014) can be classified as “low water years” in which this high-quality habitat was inundated earlier in the year but not during the fall migration period (August through September). The remaining four years (2008, 2011, 2012, and 2017) can be classified as “high water years”, during which this habitat was at least partially inundated for various portions of the study period.

During the fall study period, reservoir water levels were below average in 2009, 2010, 2013, 2014, 2015, and 2016 and above average in 2008 and 2011 (

Figure 2). In 2012 and 2017, water levels were above average for the first half of the fall study period and below average for the second half. The annual maximum water levels, dates of maximum water levels, water level on August 7, and number of days when high quality habitat was flooded during the migration period varied over the years (Table 1).

In spring, water levels of ALR are typically much lower than in fall (

Figure 2). At the beginning of the spring monitoring period (early April), low water levels typically make all stopover habitat available to migrants. While ALR fills rapidly in May and June (

Figure 2), only the lower elevation grassland habitats are usually affected by the end of the spring migration period (late May).

Table 1: Annual variation in Arrow Lakes Reservoir water levels during ten years of CLBMON-39 and CLBMON-11B2 monitoring (2008 to 2017).

Year	Max. Water Level (m)	Date of Max. Water Level	Water Level on Aug 7 (m)	Days With Water Level Over 438 m (January to September)	Days With Water Level Over 438 m (August to September)
2008	440.0	July 5	438.8	89	50
2009	437.6	June 29	436.3	0	0
2010	439.3	July 3	437.1	34	0
2011	439.6	July 28	439.4	67	33
2012	440.5	July 11	439.7	63	23
2013	440.0	July 4	435.7	28	0
2014	439.1	July 4	435.4	30	0
2015	435.5	June 13	431.7	0	0
2016	437.2	June 11	432.5	0	0
2017	439.6	July 26	439.0	67	24

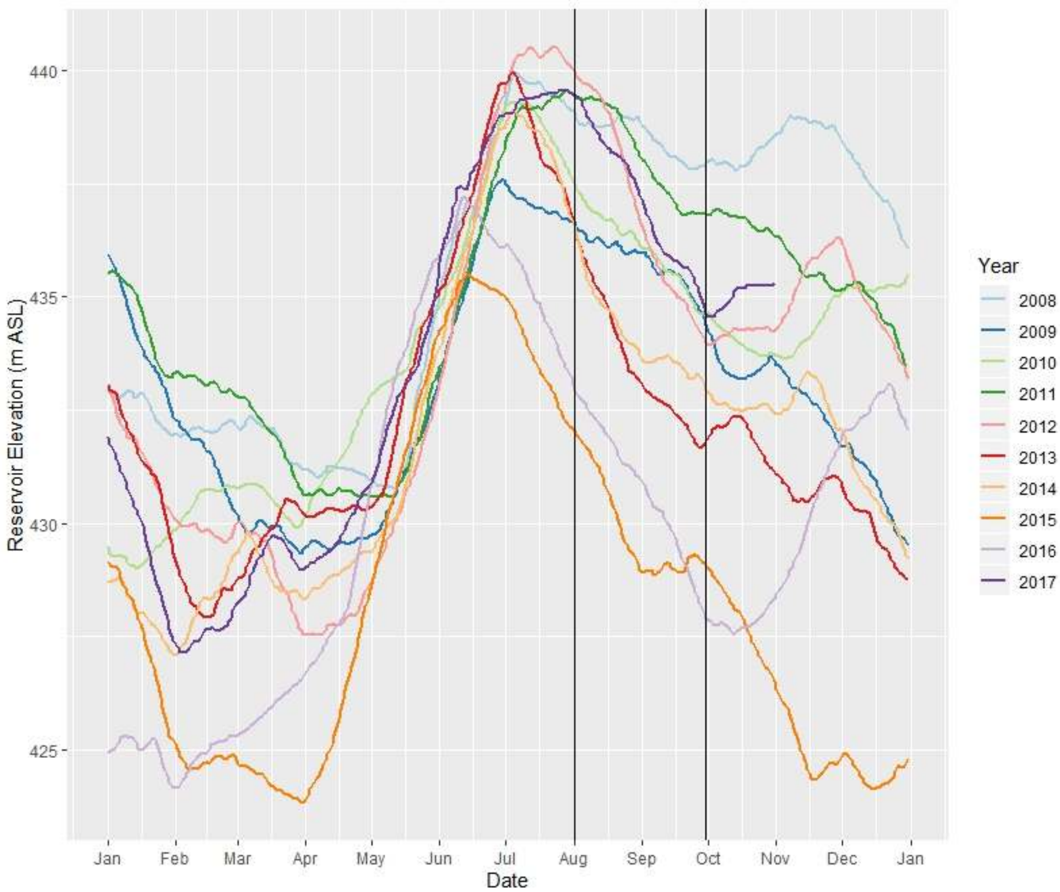


Figure 2: **Water levels (m) in Arrow Lakes Reservoir during the CLBMON-39 study period (2008 to 2017). The vertical black lines delineate the study period for this project.**

3 METHODS

3.1 Overview

Monitoring for CLBMON-39 consisted of constant effort mist netting, permanent plot sampling, random plot sampling, effectiveness monitoring of revegetation projects, assessment of migrant fattening rates through sampling of plasma metabolites, and habitat sampling. Monitoring for CLBMON-11B2 included permanent plot sampling, random plot sampling, effectiveness monitoring of revegetation projects, and habitat sampling. A brief overview of each of the components is provided below. An overview of years in which each component was conducted is provided in Table 2.

Table 2: Overview of surveys conducted in each year of CLBMON-39 and CLBMON-11B2.

Project	Survey type	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CLBMON-39	Constant effort mist netting – Machete Island - daily	o	o	o					o	o	o
	Constant effort mist netting – Machete Island - weekly				o	o	o	o			
	Constant effort mist netting – multiple stations - weekly				o	o	o	o	o	o	o
	Physiology - Machete Island	o	o	o							
	Physiology – multiple stations				o		o				
	Permanent plots				o	o	o	o			
	Random plots				o	o	o	o			
	Effectiveness monitoring - cottonwood				o	o	o	o		o	
CLBMON-11B2	Permanent plots					o	o	o		o	
	Random plots		o	o	o	o	o	o		o	
	Effectiveness monitoring - cottonwood			o	o	o	o	o		o	

3.2 Constant Effort Mist Netting

Constant effort mist netting (mist nets placed in permanent locations and opened for set periods of time) was used to assess variation in species richness, abundance, sex and age classes, and stopover length of neotropical migrants during fall migration. Constant effort mist netting surveys were conducted at five banding stations in Revelstoke Reach (Appendix A). Machete Island banding station was operated daily or weekly every fall (Table 2). Mist nets were opened 30 mins before sunrise and operated for six hours, when conditions allowed. To sample different habitats in Revelstoke Reach and to address the Management Questions in more detail, weekly monitoring at four additional banding stations was initiated in 2011. Survey effort at each station during the CLBMON-39 study period is provided in Appendix B. Detailed methods for mist net surveys are provided in CBA (2017).

3.3 Permanent Plot Sampling

Permanent plots were selected to monitor changes in neotropical migrant use of different habitats in relation to the reservoir water levels (extent of flooding of these plots). Permanent plots were established based on habitat and elevation, both in and outside of the drawdown zone (Appendix C) and were surveyed once a week. In fall (CLBMON-39), 98 permanent plots were surveyed for four years (2011 to 2014, Table 2). Permanent plots for spring migrant monitoring were established as a subsample of 23 of the 98 plots set up for fall migration studies, including lower elevation plots that were usually unavailable for fall sampling due to higher reservoir levels from July to September. In spring (CLBMON-11B2), permanent plots were surveyed in four years (2012 to 2014 and 2016; Table 2). Bird occurrence on all plots was documented for at least 10 minutes or until census saturation time (CST—the shortest time interval in which the observer was able to count all birds on the plot after the 10-minute standard survey time) was reached. However, if a plot was completely underwater with no vegetation or substrate available for migrants (open water) this plot was surveyed for only 1 minute. The order in which the plots were surveyed was changed every week to minimize bias related to the time of the day when surveys were conducted. Detailed methods for permanent plot sampling are provided in CBA (2013).

3.4 Random Plot Sampling

Random plots for migrant sampling were selected to assess neotropical migrant habitat preferences in Revelstoke Reach and to ensure non-biased coverage of Revelstoke Reach while maximizing spatial replication. To facilitate random plot selection, the Revelstoke Reach study area was stratified into broad habitat strata and habitat types (Appendix D) to ensure that even less extensive habitats were represented in sampling effort. Fall sampling (CLBMON-39) occurred in 2011 to 2014 and spring sampling (CLBMON-11B2) occurred in 2009 to 2014 and in 2016. Habitat data were collected at all random plots. Bird observations were documented for 30 minutes at each random plot. For detailed survey and vegetation sampling protocols see CBA 2013 (CLBMON-39) and CBA 2016a (CLBMON-11B2).

3.5 Effectiveness Monitoring Plot Sampling

Monitoring of plots revegetated with cottonwood stakes was conducted to document changes in use of these areas by neotropical migrants. As part of the CLBWORKS-2 project, cottonwood stakes and other deciduous species were planted in Revelstoke Reach in spring 2010 and 2011 (Keefer and Moody 2010). Effectiveness monitoring plots were located at 12 Mile (four treatment plots and two control plots), 9 Mile (six treatment plots and three control plots), McKay Creek (four treatment plots and three control plots) and Cartier Bay (one control plot). Effectiveness monitoring plots were surveyed once a week. In fall (CLBMON-39), fourteen treatment plots (planted with cottonwood stakes) and nine control plots (untreated area located in similar habitat) were monitored in 2011 to 2014 and 2016. In spring (CLBMON-11B2), the same plots were monitored in 2010 to 2014 and 2016. Bird presence on plot was documented for at least 10 minutes or until census saturation time (CST—the shortest time interval in which the observer was able to count all birds on the plot) was reached. The order in which the plots were surveyed was changed every week to minimize bias related to the time of the day when surveys were conducted. Details for effectiveness monitoring sampling are provided in CBA 2013 (CLBMON-39) and CBA 2016b (CLBMON-11B2).

3.6 Fall Neotropical Migrant Physiology

Neotropical migrant physiology was monitored to assess the effect of reservoir operation on migrant fattening rates and condition. Plasma metabolites are a useful indicator of the physiological state and fattening rate of birds (Jenni-Eiermann and Jenni 1994, Williams et al. 1999, 2007, Walker et al. 2005). The physiology of four species of neotropical migrant were studied: Yellow Warbler (*Setophaga petechia*), Common Yellowthroat (*Geothlypis trichas*), Wilson's Warbler (*Cardellina pusilla*), and Orange-crowned Warbler (*Oreothlypis celata*). From 2008 to 2010, these four focal species were captured and blood samples were taken during daily surveys at the Machete Island banding station from mid-July until the end of September. In 2011 and 2013, the scope of the physiology study was expanded to additional banding stations and two new focal species - Swainson’s Thrush (*Catharus ustulatus*) and Yellow-rumped Warbler (*Setophaga coronata*). In 2011 and 2013, the focal species were captured during weekly sampling from early August until the end of September. For detailed protocols on field sampling and plasma metabolite assays see CBA (2010b, 2013) and Wagner et al. 2014.

3.7 Habitat Sampling

Detailed vegetation data were collected at all surveyed random plots. In addition, habitat on permanent plots and effectiveness plots was documented. For a detailed vegetation sampling protocol see CBA 2013 (CLBMON-39) and CBA 2016b (CLBMON-11B2).

3.8 Permitting and Safety of Capture Birds

All banding activities were conducted under a Federal Scientific Permit to Capture and Band Migratory Birds and followed banding station protocols (CBA 2017) that follow the North American Banding Council's mist netting and bird handling safety recommendations (Smith et al. 1999, NABC 2001). During all banding operations, the welfare of captured birds was of the highest priority.

4 DATASETS

4.1 Dataset #1 (All species detected in the Revelstoke Reach)

This dataset was created to summarize presence of neotropical migrant species in Revelstoke Reach in spring and fall. Pooled data from all 10 years (2008 to 2017) and all components of CLBMON-39 were used for the fall period and data from all seven years (2009 to 2014 and 2016) and all components of CLBMON-11B2 were used for the spring period (Table 2). Unquantified presence/absence observations were included in this dataset.

4.2 Dataset #2 (Machete Island capture-recapture banding data – 10 years)

This dataset was created to describe seasonal variation in neotropical migrant abundance and species richness in Revelstoke Reach. Data collected at the Machete Island banding station were used and consisted of 10 years of capture-recapture records, from August and September only. Alder Flycatcher (*Empidonax alnorum*) and Willow Flycatcher (*Empidonax traillii*) records were pooled into one taxon – Traill's Flycatcher. Records of same day recaptures were excluded. In total, this dataset contained 21,088 capture records of 17,656 individuals of 57 species of neotropical migrant.

4.3 Dataset #3 (All components of CLBMON-39)

This dataset was created to investigate seasonal patterns of abundance of different species of neotropical migrants in Revelstoke Reach during fall migration. This dataset included data from all 10 years and all components of the CLBMON-39 monitoring (data from all five banding stations as well as data from permanent, random, and effectiveness monitoring plot surveys). Only records of neotropical migrants identified to species were included in this dataset except for Traill's Flycatcher (unidentified Willow or Alder Flycatcher). For banding data, only records of newly captured and recaptured birds were included, same day recaptures of previously banded/recaptured individuals were excluded. For plot survey data, observation of birds recorded on plot, off plot, and overhead were all included. During the ten years of monitoring, 37,543 bird records (of birds identified to species) of 73 neotropical migrant species were documented in Revelstoke Reach.

4.4 Dataset #4 (Capture-recapture banding data – three stations)

This dataset was created to assess annual variation in neotropical migrant abundance and species richness among years. This dataset included capture-recapture banding data from three banding stations located within the study area (Machete Island, Airport Islands, and Jordan River). Only newly captured birds (newly captured and banded birds and first recaptures from previous years) were included in this dataset. Alder and Willow Flycatchers records were pooled and designated as 'Traill's Flycatcher'. Data from the Machete Island banding station was compared separately for years with weekly monitoring (2011, 2012, 2013, and 2014) and for years when more rigorous daily monitoring was conducted (all other years, Appendix B). During ten years of monitoring at Machete Island banding station, 17,656 individual birds of 57 species were newly captured. Both Airport Islands and Jordan River banding stations were surveyed for seven years. At Airport Islands, 920 individual birds of 30 species were newly captured and at Jordan River 2,246 individual birds of 39 species were newly captured. In total, this dataset contained records of 20,822 individuals of 60 species of neotropical migrants.

4.5 Dataset #5 (All components of CLBMON-11B2)

This dataset was created to describe seasonal and annual variation in abundance and species richness of neotropical migrants in Revelstoke Reach during spring migration. This dataset used CLBMON-11B2 data from random plot surveys, permanent plot surveys, and effectiveness monitoring plot surveys conducted during all seven years of monitoring (2009 to 2014 and 2016). Observations of birds on plot, off plot, and overhead were all included in this dataset. In total, 10,269 bird records of 65 species of neotropical migrant songbirds were detected in spring.

4.6 Dataset #6 (Random plot survey data - fall)

This dataset was created to describe and assess neotropical migrant use of habitats in Revelstoke Reach during fall migration. Data from random plot surveys conducted during four years of CLBMON-39 fall migration monitoring (2011 to 2014) are included. Plots covered by water with no available vegetation and plots with no habitat data were excluded. Only records of neotropical migrants on plots were included (i.e., only birds which were observed to be perched, or moving within plot habitat were included). This dataset contains data from surveys of 220 random plots (44 plots in 2011, 61 in 2012, 98 in 2013, and 17 in 2014).

4.7 Dataset #7 (Random plots survey data - spring)

This dataset was created to describe and assess neotropical migrant use of habitats in Revelstoke Reach during spring migration. Data from random plot surveys conducted during seven years of the CLBMON-11B2 monitoring (2009 to 2014 and 2016) are included. Plots covered by water with no available vegetation and plots with no habitat data were excluded. If there were duplicate surveys of the same plot, only the first survey was retained. Only records of neotropical migrants on plots were included (i.e., only birds which were observed to be perched, or moving within plot habitat were included). This dataset contains data from surveys of 687 random plots (144 plots in 2009, 39 in 2010, 66 in 2011, 120 in 2012, 105 in 2013, 119 in 2014, and 94 in 2016). In total, 1458 records of 51 neotropical migrant species were documented on plots.

4.8 Dataset #8 (Capture-recapture banding data – three stations)

This dataset consisted of capture-recapture banding data from 'surveys' at three banding stations located within the study area (Machete Island, Airport Islands, and Jordan River). Each survey was a constant mist netting event that started 30 minutes before sunrise and lasted for up to 6 hours (See Section 3.2). Records of both newly captured birds and recaptures of previously banded birds (excluding same day recaptures) were included in this dataset. Alder and Willow Flycatcher records were combined into "Traill's Flycatcher". During ten years of monitoring at Machete Island banding station, 21,063 captures of 57 species of neotropical migrants were recorded. Both Airport Islands and Jordan River banding stations were surveyed for seven years. At Airport Islands, 974 captures of 30 species were recorded and at Jordan River 2,456 captures of 39 species were recorded. In total, this dataset contained records of 24,493 captures of 60 species neotropical migrants. Survey effort in each year and for each station is provided in Appendix B, however four surveys with less than 12 net-hours were excluded in this dataset (two surveys at Machete Island in 2015, one survey at Airport Island in 2017, and one survey at Jordan River in 2016). This dataset contained 430 surveys, 306 at Machete Island, 57 at Airport Islands, and 67 at Jordan River.

4.9 Dataset #9 (Permanent plot survey data)

This dataset was created to assess the effect of reservoir operations on the use of stopover habitat in the drawdown zone by neotropical migrants. Data were collected on 98 different permanent plots during fall migration monitoring from 2011 to 2014; however, 86 of these were standardized 50 x 50 m plots or irregularly shaped plots of comparable size (0.25 ± 0.2 ha), and only these latter comparable plots were included in this dataset. Only records of neotropical migrants on plots were included (i.e., only birds which were observed to be perched, or moving within plot habitat were included). Plots were surveyed regardless of reservoir water levels and as such this dataset contained samples of plots surveyed under various flooding scenarios. In total, data from 2,788 surveys conducted in 2011 to 2014 (2011: n=582, 2012: n=773, 2013: n=771, 2014: n=662) were included. In total, 3,639 neotropical migrants of 49 species were recorded on plot.

4.10 Dataset #10 (Effectiveness monitoring plot survey data - fall)

This dataset was created to assess the effect of revegetation treatment on fall neotropical migrant abundance and species richness. Fall surveys at 14 treatment plots (planted with cottonwood stakes) and 9 control plots (untreated area located in similar habitat) were monitored for five years (2011 to 2014 and 2016). Only records of neotropical migrants on plots were included (i.e., only birds which were observed to be perched, or moving within plot habitat were included). Data was from 919 surveys during which 663 neotropical migrant songbirds of 24 species were recorded on plot.

4.11 Dataset #11 (Effectiveness monitoring plot survey data - spring)

This dataset was created to assess the effect of revegetation treatment on spring neotropical migrant abundance and species richness. This dataset contained data collected on 14 treatment plots (planted with cottonwood stakes) and eight control plots (untreated area located in similar habitat) over a period of six years for the 12 Mile area (2010 to 2014 and 2016) and for a period of five years (2011 to 2014 and 2016) for the other treatment sites. Only surveys in weeks that were monitored in all years of monitoring (for each site) were included (12 Mile area plots had five surveys per year, 9 Mile area plots had four surveys per year, McKay Creek area had five surveys per year, and 9 Mile point had four surveys per year). In total, this dataset contained 577 surveys (12 Mile area = 180 surveys, 9 Mile area = 148 surveys, 9 Mile point area = 40 surveys, and McKay Creek area = 209 surveys). Only records of neotropical migrants perched or moving within plot habitat were included and records of 336 neotropical migrants of 22 species were analyzed.

5 ANALYSES

All statistical analyses were performed in R statistical software (R Core Team 2019) unless otherwise stated. A two-tailed alpha, set at 0.05, was used for all tests, unless otherwise stated. Only records of neotropical migrant songbirds (ECCC 2017) were analyzed in this report. Bird species names and codes are provided in Appendix E.

6 MANAGEMENT QUESTIONS – CLBMON-39

6.1 MQ-1: What is the seasonal and annual variation in the abundance and species richness of neotropical migrants in Revelstoke Reach during fall migration?

Although this MQ only considers fall migration, data from spring migration gathered under CLBMON-11B2 are also reviewed in this section; as such, this MQ is addressed for both seasons.

6.1.1 Seasonal variation in abundance and species richness

During ten years of fall migration monitoring, 73 neotropical migrant species were recorded in Revelstoke Reach (Appendix E). The abundance of migrants varied throughout the fall migration season (Appendix F, Appendix G). In late July, prior to the main monitoring period (August to September), the abundance of neotropical migrants was relatively stable (CBA 2010a, 2011) and most migrants present in the drawdown zone were local breeders and juveniles.

From the beginning of August, the abundance of neotropical migrants increased, and peaked in late August, and then declined through September (Figure 3, Appendix F). At the end of September, the overall abundance of migrants in Revelstoke Reach was relatively low (at the lowest point for the fall migration period, Figure 3). While some late season migrants (e.g., American Robin - *Turdus migratorius*, Yellow-rumped Warbler, Orange-crowned Warbler, sparrow species - Passerellidae, American Pipit - *Anthus rubescens*) were present in Revelstoke Reach after the end of September, the overall abundance of migrants steeply decreased.

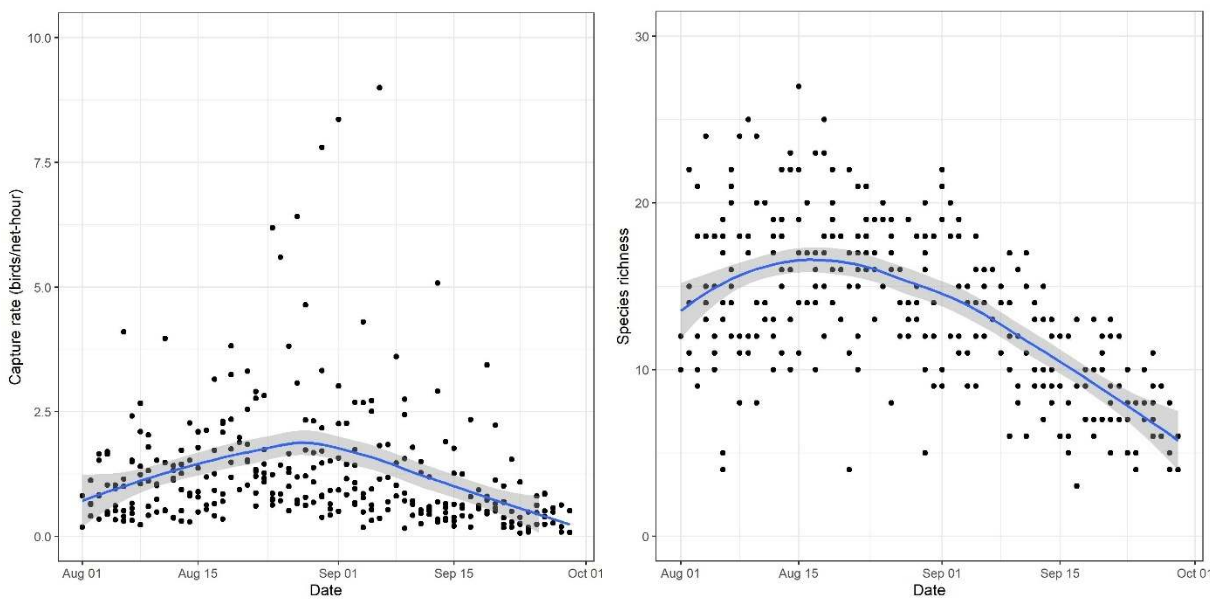


Figure 3: (LEFT) Seasonal variation in abundance (daily capture rate) of neotropical migrant songbirds in Revelstoke Reach throughout the fall migration season (2008 to 2017 data from Machete Island banding station). Loess smoother (blue line) with 95% confidence interval (gray shaded band). (RIGHT) Seasonal variation in daily species richness of neotropical migrant songbirds in Revelstoke Reach throughout the fall migration season (2008 to 2017 data from Machete Island banding station). Loess smoother (blue line) with 95% confidence interval (gray shaded band).

Species richness of neotropical migrants in Revelstoke Reach also varied throughout the fall migration season. Species richness was higher in the first half of the season (August), with the peak around mid-August, followed by a sharp decline through September (Figure 3, Appendix F).

Patterns of both seasonal abundance and seasonal species richness of neotropical migrants in Revelstoke Reach showed considerable variation among years (Appendix F; Figure F-1 and Figure F-2). Observed annual variation in seasonal abundance was largely driven by differences in abundance of some common species among years (e.g., Yellow-rumped Warbler). Different species tend to reach their peak of abundance at different points within the migration season (Appendix G; Figure G-1), which in turn can influence the overall pattern of abundance. The pattern of seasonal species abundance and peak migration timing observed in this study is consistent with fall migration timing for southeastern British Columbia (Campbell et al. 1997, 2001).

A diversity of early fall migrants (e.g., flycatchers - Tyrannidae, vireos - Vireonidae, Veery - *Catharus fuscescens*, Yellow Warbler, American Redstart - *Setophaga ruticilla*, Northern Waterthrush - *Parkesia noveboracensis*, MacGillivray's Warbler - *Geothlypis tolmiei*, Lazuli Bunting - *Passerina amoena*) reach peak abundance at Revelstoke Reach during the month of August and decline through the rest of the survey season; these species account for the bulk of overall abundance early in the season (Figure 3). Common Yellowthroat, the most frequently recorded fall migrant species in Revelstoke Reach, is present in the area during the whole season with a clear peak in the middle of the season (late August-early September); this species therefore contributes to the later peak in overall abundance (Figure 3). There are also several late fall migrants (e.g., Ruby-crowned Kinglet - *Regulus calendula*, Orange-crowned Warbler, Yellow-rumped Warbler, Wilson's Warbler, Lincoln's Sparrow - *Melospiza lincolnii*) that are reliably more abundant in the second half of the season (Appendix G; Figure G-1).

Some species are present in Revelstoke Reach more uniformly throughout the whole fall survey season. This is especially true for: 1) species without well-defined seasonal latitudinal migration (e.g., Pine Siskin – *Spinus pinus*), 2) migrants at the northern limit of their breeding range with very few migrants passing through Revelstoke Reach from further North (e.g., Gray Catbird – *Dumetella carolinensis*), or 3) later migrating species that use the Revelstoke Reach area through the whole monitoring period (e.g., Savannah Sparrow – *Passerculus sandwichensis*, Song Sparrow – *Melospiza melodia*).

6.1.2 Annual variation in abundance and species richness

The overall abundance of neotropical migrants in Revelstoke Reach varied considerably among years. Comparing the annual capture rate of neotropical migrants at two banding stations in the drawdown zone, as well as a banding station outside of the drawdown zone, there were significant annual differences in capture rate among years at all three stations (Figure 4, Table H-1, Table H-2). Over the ten-year monitoring period, the overall annual capture rate at Machete Island in a year when migrant abundance was high (2017) was more than 3.5-times that of the lowest year (Table H-1). Year 2017 had particularly high numbers of migrants present in Revelstoke Reach and the capture rate in that year was higher than average at all banding stations. The high abundance of neotropical migrants using the drawdown zone in the fall of 2017 was most likely driven by the high breeding productivity in that season, as a majority of captured migrants were juvenile birds (CBA 2018), which is typical for migrant age composition during fall migration. However, not all banding stations in BC recorded an above average number of fall migrants in 2017 (e.g., Cameron 2017, MNO 2017). It is possible that the extensive wildfire activity in the BC interior during summer and fall of 2017 could also have contributed to the high numbers of migrants using Revelstoke Reach by funneling migrating songbirds through areas with less fire activity.

Similar to overall abundance, the annual abundance of the 10 most frequently captured species varied significantly among years (Table H-3, Table H-4, Table H-5,

Table H-6). Of the species captured in every year of monitoring, Yellow-rumped Warbler had the greatest fluctuation in abundance among years (Figure H-1). During fall migration monitoring, a variation in abundance of different fall migrants among years is expected, as their abundance is to a large extent driven by the number of juvenile birds and hence dependent on annual productivity.

While there were small differences in species richness among years (Table H-1), species richness did not significantly differ among years at any banding station (Table H-2). Most common and abundant species of migrants were captured every year (Figure H-1). The differences in species richness among years were mostly driven by uncommon species whose low numbers did not affect overall abundance. Of the 73 species of neotropical migrants recorded during fall migration (all components of CLBMON-39), 36 species were documented in all years of monitoring (Figure I-1).

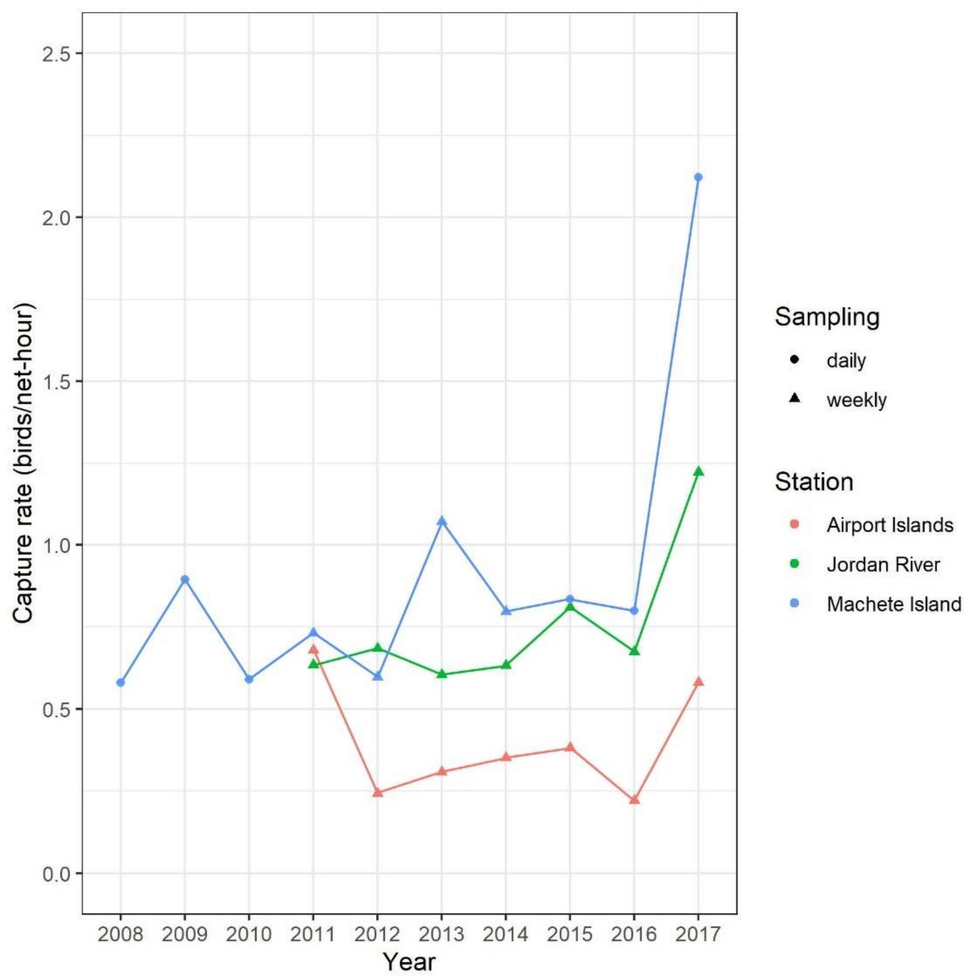


Figure 4: **Annual variation in abundance (overall annual capture rate) of neotropical migrant songbirds at three banding stations in Revelstoke Reach during fall migration (2008 to 2017).**

6.1.3 Spring variation in abundance

During spring monitoring under CLBMON-11B2, 65 species of neotropical migrant songbirds were detected in Revelstoke Reach. The timing and intensity of spring migration for all recorded species can be seen in Figure J-1. The seasonal variation in abundance of neotropical migrants during spring migration was consistent with the timing of spring migration for this broad geographical area (Campbell et al. 1997, 2001).

There were notable differences in the detected species and their abundances when compared to the data collected during fall migration monitoring. Some of the most frequently recorded species during spring migration (e.g., American Pipit, American Robin, swallows - Hirundinidae, Chipping Sparrow – *Spizella passerina*, White-crowned Sparrow – *Zonotrichia leucophrys*) were not the most abundant during fall migration. Conversely, common species during fall migration (e.g., Traill's Flycatcher, American Redstart, Swainson's Thrush, Red-eyed Vireo – *Vireo olivaceus*) were recorded low numbers in spring.

This difference in frequently observed species was, in some cases, caused by uneven sampling between seasons. In spring, sampling was conducted exclusively through plot surveys while in fall it was a combination of plot surveys and mist netting. In addition, the timing of spring migration monitoring targeted early to mid-season migrants (April-May) and this may have resulted in the low numbers of late spring migrants like Traill's Flycatcher, Red-Eyed Vireo or Swainson's Thrush (that are abundant during fall migration) recorded. Similarly, the timing of fall migration monitoring (Aug-Sep) targeted early to mid-season fall migrants, therefore some very late migrants (e.g., American Robin - which was frequently recorded in spring) were not recorded nearly as frequently in fall.

Another factor influencing the difference in dominant species between spring and fall was the availability of high elevation stopover habitat during fall migration. High elevation habitat has been known to provide high quality stopover habitat for migrating songbirds (Ogden et al. 2013), and in the Revelstoke area this habitat is intensively used by migrants during fall migration (M. Pavlik, unpublished data). In spring, this habitat is unavailable to spring migrants due to snow cover. As such, the use of high elevation stopover habitat during fall by some migrants (e.g., American Pipit, White-crowned Sparrow) therefore also partly explains the differences in dominant species recorded in Revelstoke Reach during fall and spring migration.

6.1.4 Effects, Challenges, and Opportunities

The large dataset collected over the course of CLBMON-39/11B2 studies (2008 to 2017), has allowed for the description of seasonal and annual patterns of neotropical migrant abundance and species richness in Revelstoke Reach in great detail.

There are a wide range of species using Revelstoke Reach for stopover habitat in spring and fall, but a few common species dominate the numbers observed. While there may be additional species added to the list of migrants if monitoring were to be continued, these would be incidental and not likely valuable to consider when making land management decisions.

Variation in species' abundance between years driven by events on the breeding or wintering grounds cannot easily be assessed in this study. Higher numbers of fall migrants are expected in years with high reproductive success in the summer, and higher numbers of spring migrants in years with higher winter survival. Variation in species' abundance and diversity driven by reservoir operations is considered in MQ-5.

As noted above, the temporal scheduling of the monitoring periods likely created some bias related to which species were recorded in spring versus fall migrations. The truncation of monitoring periods prevented collecting data on a relatively small proportion of late migrants in both seasons.

6.2 MQ-2: Which habitats within the drawdown zone in Revelstoke Reach are utilized by neotropical migrants and what are their characteristics?

This CLBMON-39 MQ is addressed below for both migrations, which were monitored under CLBMON-39 in fall and under CLBMON-11B2 in spring.

6.2.1 Fall Usage Across Broad Habitat Strata

Four broad habitat strata were used to describe vertical vegetation complexity of habitat used by neotropical migrants in Revelstoke Reach. At the lowest elevations in the drawdown zone (below ~433 m), unvegetated habitats are present. At elevations above 433 m, grassland habitat is dominant with shrub habitat becoming increasingly common with rising elevation (above ~436 m). At the highest elevations in the drawdown zone (above ~439 m), forest habitat is present in some areas.

In Revelstoke Reach, both abundance and species richness of neotropical migrants was highest in the forested habitat, followed by shrub habitat and grassland habitat (Figure 5**Error! Reference source not found.**, Appendix K). As expected, unvegetated habitat had the lowest abundance and species richness of neotropical migrants (Appendix K). These findings conform to expectations that habitats with higher vertical vegetation structure would provide stopover habitat for more species and more individuals of neotropical migrants. As the vertical vegetation structure decreases, so does the number of species that can be supported by these habitats, with unvegetated habitat capable of supporting only a very few species of neotropical migrants.

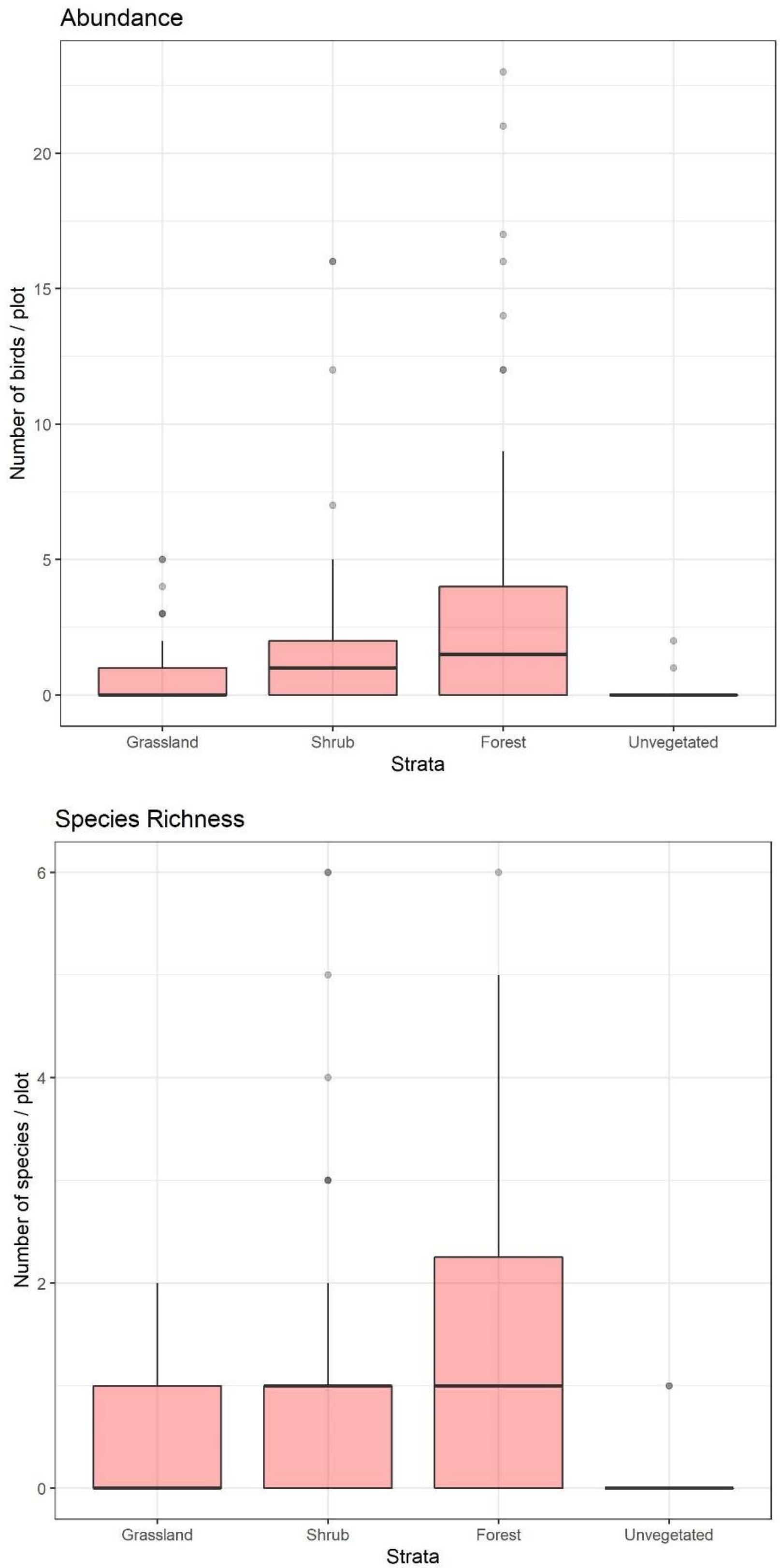


Figure 5: **Abundance and species richness of fall neotropical migrants in Revelstoke Reach among habitat strata (plot = 0.25 ha).**

6.2.2 Fine Habitat Usage During Fall Migration

In addition to the comparison of migrant use of the drawdown zone by broad habitat strata, neotropical migrant abundance and species richness was assessed among the 28 habitat types identified in Revelstoke Reach (Appendix D, CBA 2016b). Habitat use was not proportional to habitat availability.

The habitat types were not evenly distributed in Revelstoke Reach. The three most extensive habitat types, mixed grassland, shrub savannah, and sedge grassland, covered more than 50% of the drawdown zone area. Conversely, 14 habitat types each cover less than 1% of the drawdown zone area (Appendix D).

In general, both abundance and species richness were highest in well-developed riparian habitats (e.g., riparian forest or riparian shrub habitat) and wetland habitats with complex vertical structure (e.g., swamp, wet meadow, cattail habitat; Appendix L) none of which were common (Appendix D). Conversely, neotropical migrants used the widespread open grassland or unvegetated habitat types less intensively (Appendix L).

The fall migrant density in the drawdown zone of Revelstoke Reach was modelled based on the average abundance in each habitat type (pooled data for all species). A map of modelled fall migrant density shows the relatively small amount of area in the drawdown zone that is most heavily used by fall migrants (Figure 6).

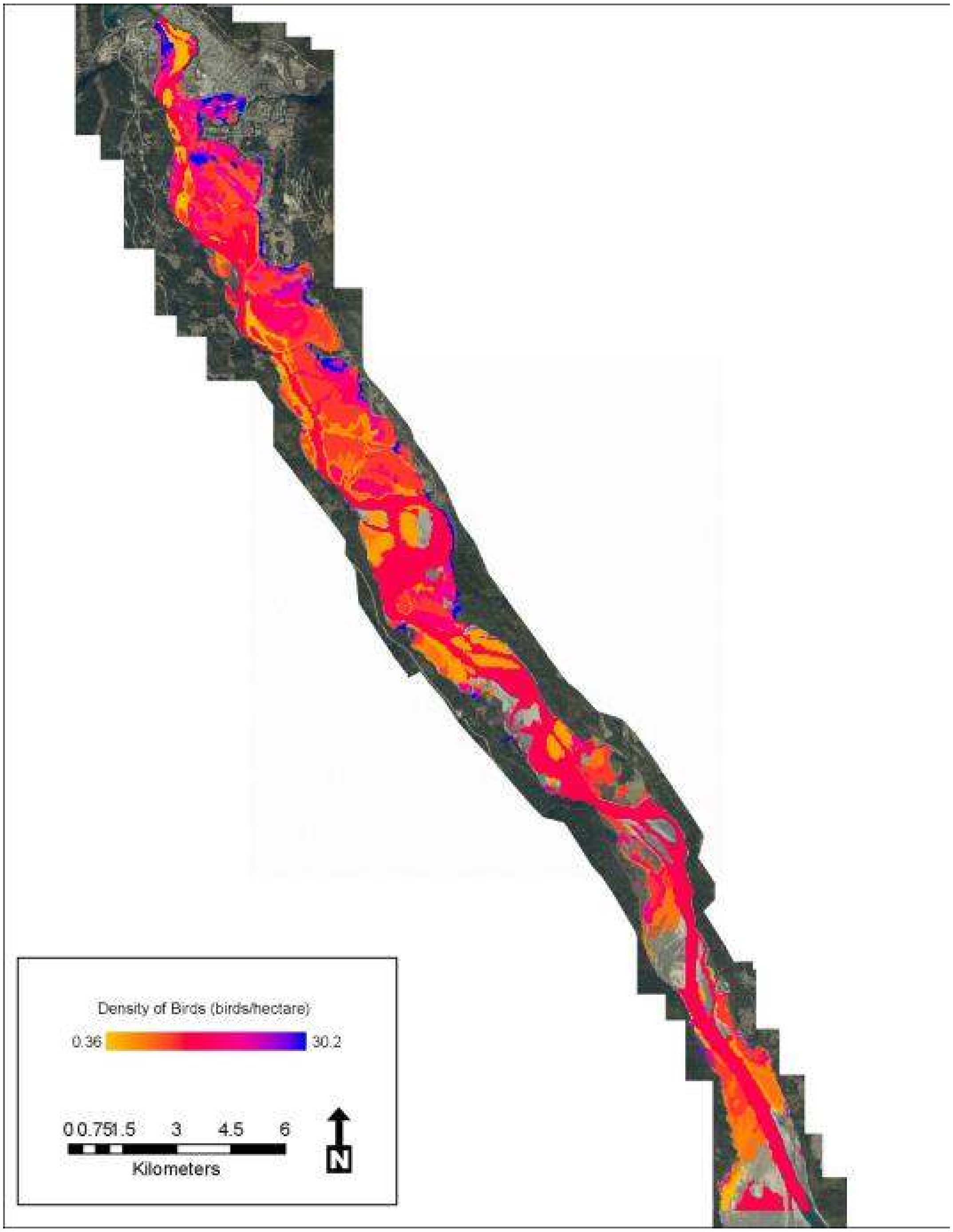


Figure 6: Modelled neotropical migrant songbird density in Revelstoke Reach during fall migration (pooled data from all species).

To further investigate neotropical migrant habitat preferences in the drawdown zone, the effect of vegetation cover (tree, shrub, and herbaceous cover) on abundance and species richness of migrants on plots was assessed. Of the three types of vegetation cover, shrub cover had the strongest effect on abundance of neotropical migrants on plot, with migrant abundance increasing with increasing shrub cover on plot (Appendix N). Tree cover also had a positive effect on neotropical migrant abundance on plot while herbaceous cover had no effect on migrant presence on plot and only a weak negative effect on the quantity of detected birds (Appendix N). Species richness was positively affected by increasing tree and shrub cover on plot and negatively affected by increasing herbaceous cover on plot (Appendix N). In general, greater vertical vegetation structure (presence of shrubs and trees) increases the neotropical migrant abundance and species richness in the drawdown zone.

6.2.3 Habitat Use by Species During Fall Migration

Different species of neotropical migrants have different habitat preferences, therefore the habitat preferences of Common Yellowthroat (the most abundant fall migrant in the drawdown zone) and three main families of fall migrants: tyrant flycatchers (Tyrannidae), wood-warblers (Parulidae), and sparrows (Passerellidae) were investigated.

As expected, flycatchers and wood-warblers had the highest average abundance on plots in forest habitat, while Common Yellowthroat and sparrows had the highest average abundance on plots from the shrub habitat (Table M-1). The average abundance of flycatchers, wood-warblers, sparrows, and Common Yellowthroat also varied among habitat types. The abundance of flycatchers was highest in swamp habitat type, the abundance of wood-warblers was highest in riparian forest habitat type, and the abundance of sparrows was highest in wet meadow habitat type (Table M-2). Common Yellowthroat had the highest abundance in cattail habitat type (Table M-2). A map of modelled density of each of the three groups of migrants (flycatchers, wood-warblers, and sparrows) and Common Yellowthroat during fall migration in Revelstoke Reach is provided in Figure M-1.

The relationship between vegetation cover on plot and abundance of migrants also varied depending on individual species preferences. For wood-warblers, only shrub cover had a significant positive effect on their presence on plots (Appendix N). Presence of sparrows on plots increased significantly with increasing herbaceous cover and, to a lesser extent, decreasing tree cover (Appendix N). The presence of Common Yellowthroat on plots was weakly and positively affected by increasing herbaceous cover and weakly and negatively affected by the percent of tree cover (Appendix N). These results support the expected habitat preferences of these two families of migrants and match their habitat and foraging strategies elsewhere in BC (Campbell et al. 1997, 2001). Most wood-warblers prefer to forage in shrub and tree canopy and rarely use herbaceous vegetation. Conversely, Common Yellowthroat, as one of a few wood-warblers, prefers to forage in dense vegetation close to the ground. Similarly, sparrows, in general, prefer to forage on the ground or in low vegetation.

6.2.4 Spring Migration Monitoring

During spring migration in Revelstoke Reach, the abundance and species richness of neotropical migrants varied among habitat strata. Both abundance and species richness of neotropical migrants was highest in the forested habitat, followed by shrub habitat, grassland habitat, and unvegetated habitat (Figure 7, Appendix O). Compared to the habitat use during fall migration, unvegetated habitat was used by migrants more frequently in spring. The relatively high number of migrants observed in unvegetated habitat in spring was primarily driven by records of American Pipit, which used this habitat frequently. However, during fall migration, American Pipit were recorded only in small numbers despite availability of unvegetated habitat in some years (in most years unvegetated habitat was minimally or not available during fall migration).

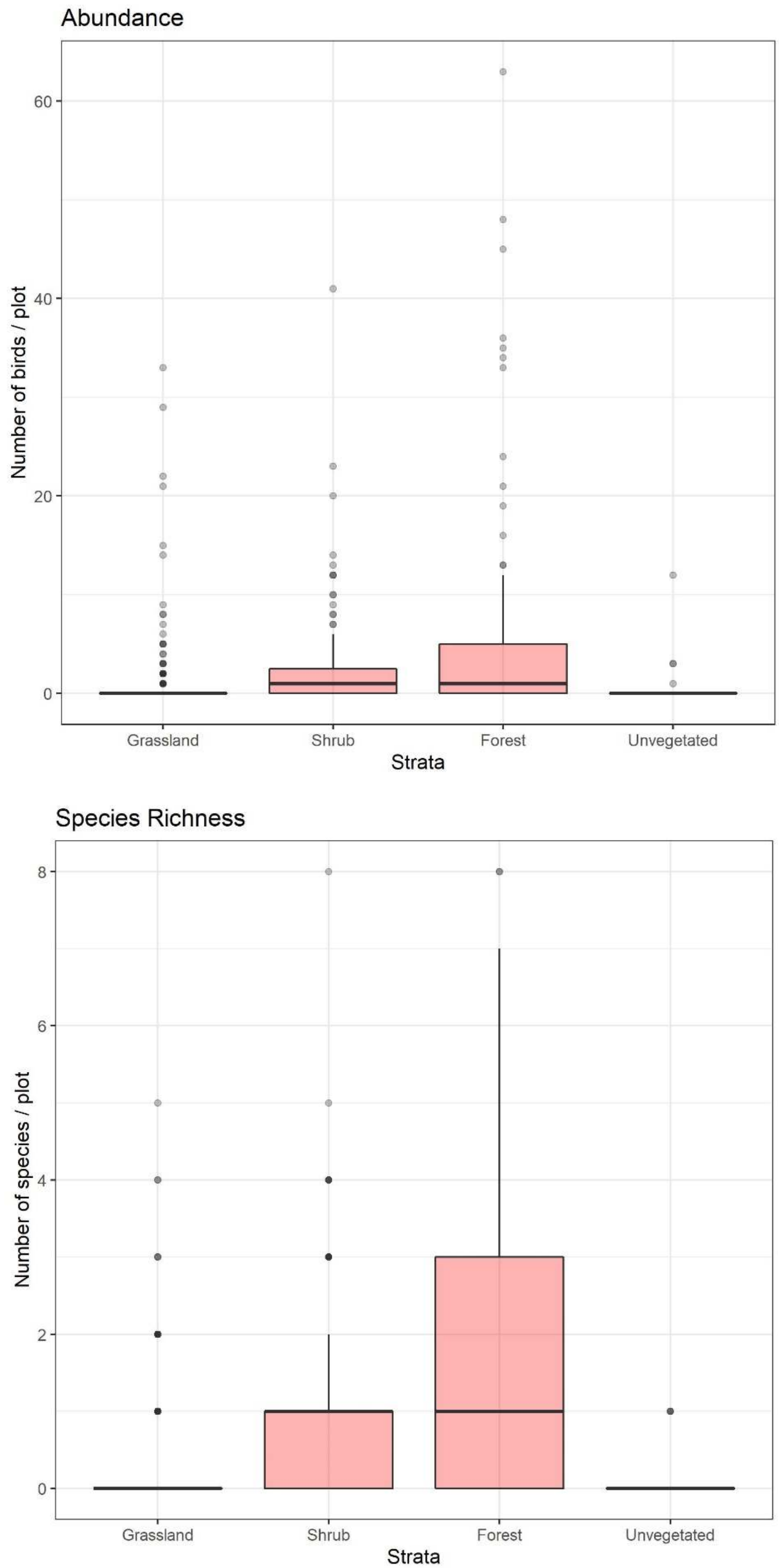


Figure 7: **Abundance and species richness of spring neotropical migrants in Revelstoke Reach among habitat strata (plot = 0.25 ha).**

In spring, overall abundance and species richness of neotropical migrants also varied among habitat types (Table P-1). In general, both abundance and species richness were highest in forested habitat types (riparian and upland forest habitat), well-vegetated wetland habitat types (swamp habitat, cattail habitat), and shrub savannah. A map of modelled spring migrant density in Revelstoke Reach (all species pooled together) is provided in Figure 8 (Appendix P).

Similar to fall migration, different species used different habitats within the drawdown zone in spring and their abundance in various habits reflected this. Flycatchers and wood-warblers were the most abundant in forest habitat, sparrows in shrub habitat, and American Pipit in grassland and unvegetated habitats (Table Q-1). Among the habitat types identified in Revelstoke Reach, American Pipits reached the highest average abundance in the sedge grassland habitat type, silt habitat, and low elevation draw habitat (Table Q-2). The abundance of sparrows was highest in cattail habitat, floating bog habitat, and swamp habitat, and the abundance of wood-warblers was highest in forest habitat types (upland forest and riparian forest habitat) as well as floating bog, cattail, and shrub savannah habitat types (Table Q-2). A map showing modelled average spring density of wood-warblers, sparrows, American Pipit, and Yellow-rumped Warbler in Revelstoke Reach during spring migration is provided in Figure Q-1. In general, the habitat preferences in spring are similar to the habitat preferences documented during fall migration. Overall, while some species prefer open habitats (e.g., American Pipit), the neotropical migrant abundance and species richness was higher in habitats with greater vertical vegetation structure and this further confirms the importance of shrub and forest habitat for migrating songbirds in Revelstoke Reach.

Tree cover and shrub cover had a positive effect on the presence of migrants on plot, but did not affect the numbers of observed migrants (Appendix R). Species richness of neotropical migrants was positively affected by tree cover and shrub cover, but was not affected by herbaceous cover on plots (Appendix R).

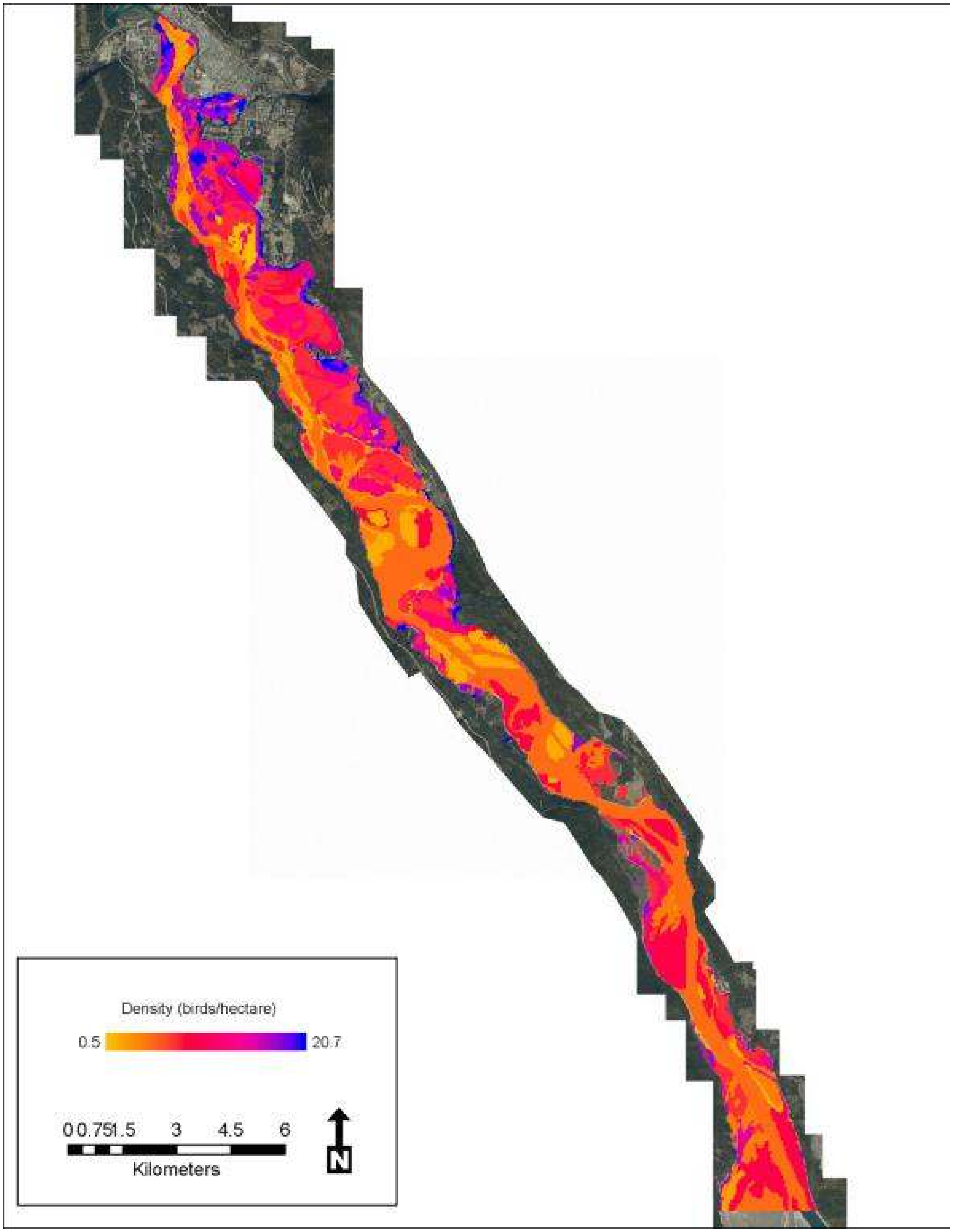


Figure 8: **Map of modelled neotropical migrant songbird density in Revelstoke Reach during spring migration (pooled data from all species are plotted).**

6.2.5 Effects, Challenges, and Opportunities

Overall, the use of habitat in Revelstoke Reach by neotropical migrants has been well documented through analysis of random plot data which included both bird data and vegetation data. A robust sample of 220 fall and 687 spring random plots with detailed vegetation data allowed us to describe and compare use of habitat by neotropical migrants both among broad habitat strata and based on vegetation cover on plot. In addition, it allowed for the comparison of the habitat preferences of two dominant families of neotropical migrants (wood-warblers and sparrows) using the drawdown zone habitat during spring and fall migration.

On a finer scale, neotropical migrant habitat preferences were described using Revelstoke Reach habitat type mapping (CBA 2013b). However, care must be taken when generalizing these results. First, some of the sampled habitat types (e.g., swamp, cattail), while heavily used by migrants, cover only small and very localized areas. As such, there were a limited number of random plots surveyed, in some cases as low as only two surveys. In addition, random plots were assigned to the habitat type based on the dominant habitat type on the plot. In cases where a habitat type was sampled only by a limited number of surveys, presence of a different, highly productive habitat type on a small portion of the plot could bias the overall estimate. For example, even a very small patch of highly productive habitat (e.g., shrubs or riparian forest) on an otherwise unvegetated plot could, because of the limited sample size, bias the overall estimate of the abundance and species richness for that habitat type. Data for all habitat types, even the ones with limited sample sizes, are presented because they still provide useful insight on neotropical migrant use of these rare and localized habitat types. However, care must be taken when interpreting and generalizing any results based on the data from habitat types with limited sample size.

6.3 MQ 3: Do reservoir operations influence the species richness or abundance of neotropical migrants using habitat in the drawdown zone during fall migration? If so, how do reservoir operations influence species richness or abundance?

In the drawdown zone, the impact of reservoir operations varies based on the elevation, with areas positioned lower in the drawdown zone being affected more intensively by reservoir water levels than those positioned near the full pool mark. In addition, given the same extent of flooding, two habitats with different vertical vegetation structure may experience different severity of this impact. As such, the effect of reservoir operations on the neotropical migrant abundance and species richness was not uniform for the entire drawdown zone but varied based on habitat (which was strongly influenced by elevation). For this study, we approached this MQ at the scale of habitat classes (strata), as measured at the scale of monitoring plots, and we also review research conducted at specific banding station areas.

6.3.1 Plot-based Inference

Reservoir operations definitely affected the abundance and species richness of neotropical migrant songbirds, but this effect depended on the type of habitat being considered in the drawdown zone. In general, the lower elevation habitats were more influenced by reservoir operations, with observable impacts to abundance and species richness. However, these habitats (e.g., grasslands and shrub savannah) are less important for most neotropical migrants we considered. The most important habitats (e.g., riparian shrub, forest) were less influenced by reservoir operations, and there was little evidence of impacts to the vast majority of neotropical migrants.

At the scale of monitoring plots, analysis of the data collected on permanent plots during the fall revealed that, as expected, plots that were entirely flooded with no vegetation or ground cover available were not used by migrating songbirds (Appendix T). Reservoir operations influence species richness and abundance during the fall migration because a diversity of species are known to use habitats which may become entirely inundated.

On plots where at least some habitat was available, the effect of flooding (water depth on plot) varied based on habitat strata. On grassland and shrub plots, the probability of presence of neotropical migrants was significantly lowered with increasing water depth (Figure 9 and Figure 10, respectively; Appendix T). There was no significant effect of water depth on presence of migrants on forest plots (Figure T-1), though forest plots are positioned higher in the drawdown zone and do not experience the same intensity of flooding as grassland or shrub plots.

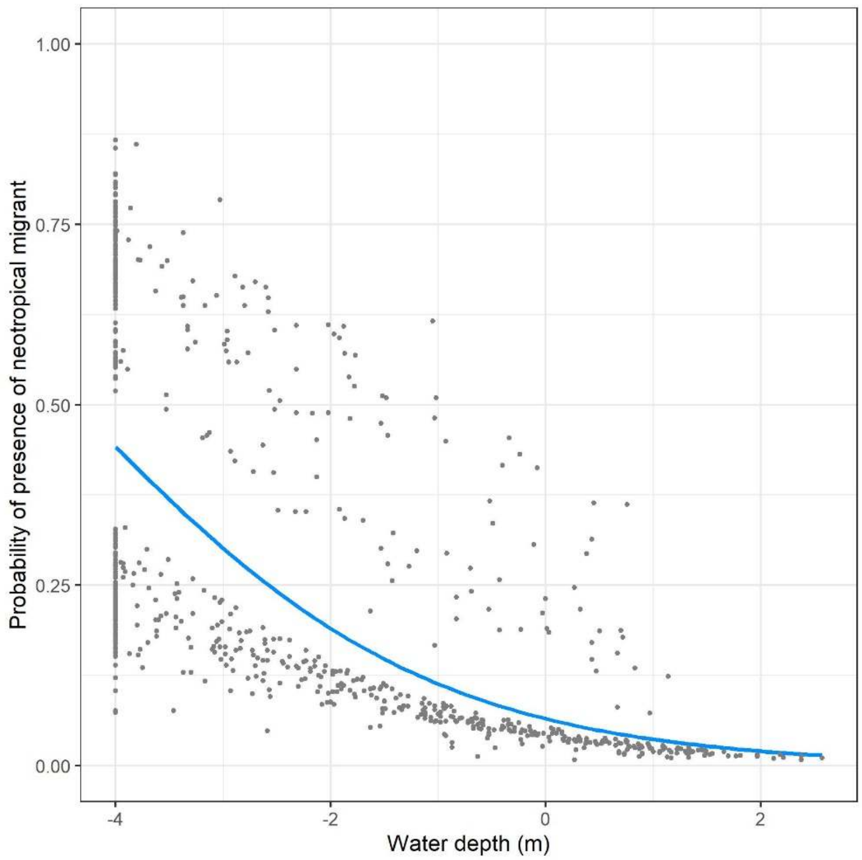


Figure 9: **Probability of presence of neotropical migrants on grassland plots based on varied water depth on plot. Blue line = model prediction (after controlling for time after sunrise, Julian date and year). Partial residuals are plotted in gray (Appendix T).**

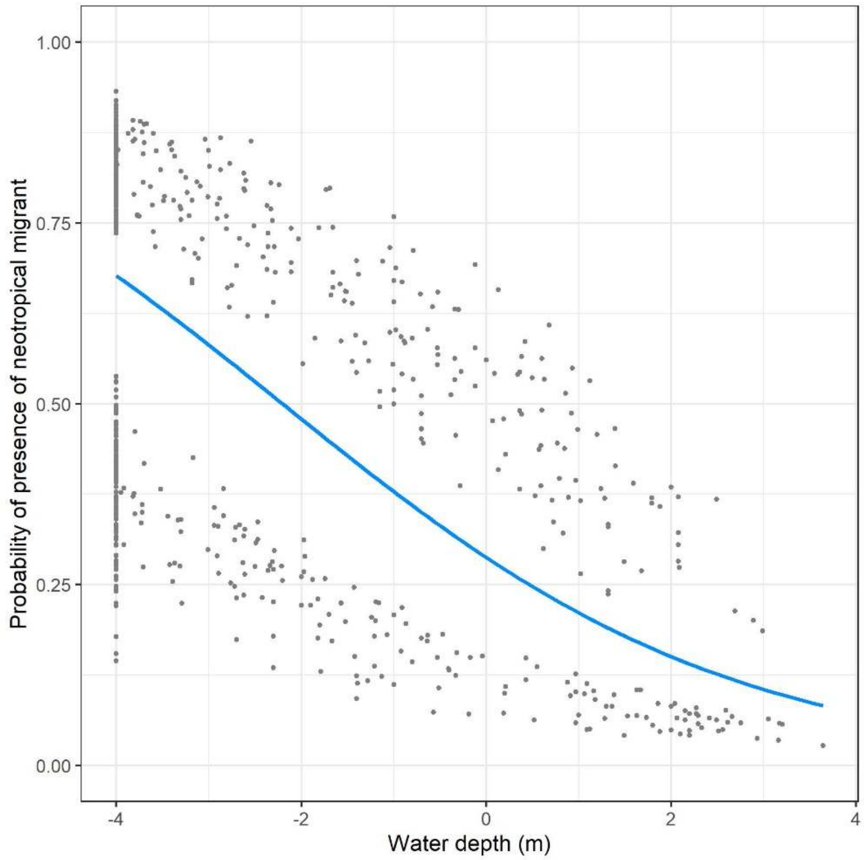


Figure 10: **Probability of presence of neotropical migrant on shrub plots based on varied water depth on plot. Blue line = model prediction (after controlling for time after sunrise, Julian date and year). Partial residuals are plotted in gray (Appendix T).**

6.3.2 Impacts to Results at Banding Stations

The banding stations monitored usage of stopover habitat by neotropical migrants at two locations within the drawdown zone, and one location above the drawdown zone. One drawdown zone location (Airport Islands) was within the Shrub strata, the other (Machete Island) was in the Forest strata. Airport Islands banding station is at a lower elevation (~ 437 m above sea level (ASL)) and experiences more frequent and longer flooding events than Machete Island (~ 439 m) (Figure 11). Jordan River banding station is situated outside of the drawdown zone and is not directly influenced by reservoir operations.

Figure 11: Net lane at Airport Island banding station in a year with high water levels (left, August 21, 2012) and the same net in a year with low water levels (right, August 25, 2014)

While there were significant differences in bird abundance among years (as measured by capture rate), neither daily water level at the banding site nor whether the banding site (or part of it) has been flooded in the current year had an effect on daily capture rates at stations in the drawdown zone (Machete Island and Airport Islands; Appendix S). For daily species richness, the only support for and effect of reservoir operation was found at Airport Islands, where there was a marginally negative affect of daily water levels at the site on daily species richness (Appendix S).

In addition, three measures of reservoir operations were used to assess effects on neotropical migrant annual abundance (as measured by overall annual capture rate) at banding stations: (1) maximum annual reservoir water level, (2) reservoir water level on August 7, and (3) the number of days in the January to September period with water level over 438 m. There was no consistent relationship between annual bird abundance (capture rate) and the three measures of reservoir operations, comparing sites in the drawdown zone and a control site outside the drawdown zone (Figure S-1). Assessing stopover length at Machete Island, there was no significant difference in stopover length among years with different reservoir operations (Figure S-2).

6.3.3 Discussion

The use of grassland plots and shrub plots by migrants decreased with increasing water depth on plot, while the use of forested plots was not significantly affected. With increasing water, grassland areas become less attractive to migrants. While some species can use partially flooded grassland habitat (e.g., Common Yellowthroat), most other species that frequent grassland habitat (e.g., Savannah Sparrow) generally do not use flooded grassland. In addition, due to the lower vertical vegetation structure compared to shrub or forest habitat, and lower relative elevation in the drawdown zone, grassland habitat and the lower elevation habitat in general is impacted by reservoir operations more frequently. One mitigating factor is that the species utilizing lower elevation grassland habitats (e.g., American Pipit, sparrows) migrate, in general, later in the season when reservoir water levels are usually lower compared to what early fall migrants experience. Conversely, habitats positioned higher in the drawdown zone (forest and shrub) are impacted less frequently and even if they do get inundated, they still provide valuable stopover habitat for migrants due to their vertical structure protruding above the water surface.

Analyzing detailed capture-recapture data collected at the Machete Island banding station revealed that neotropical migrant abundance and species richness in this highly utilized stopover habitat was not influenced by the reservoir operations (Appendix S). This is consistent with a previous study conducted at Machete Island banding station, where no consistent effect of reservoir water levels on capture rates of wood-warblers was found (Green et al. 2011). At the banding station positioned lower in the drawdown zone (Airport Islands) there was a marginally negative relationship between daily species richness (but not daily capture rate) and daily water level at the site (Appendix S). This adds to the evidence that the lower elevation habitats are more likely to be negatively affected by reservoir operations; however, these habitats are also used much less intensively by migrants (CBA 2012, 2014, 2015).

Considering that the neotropical migrant utilization of the highly productive stopover habitat (positioned higher in the DDZ) during fall migration is not significantly affected by reservoir operations and that the lower elevation habitat is utilized only by a relatively small number of neotropical migrants (even if unaffected), the reservoir operations' impact (within the range observed during the study period) on the overall neotropical migrant abundance and species richness in Revelstoke Reach is likely limited (except for a few grassland obligate species).

However, it is important to note that the valuable stopover habitat in the drawdown zone is, to a large extent, dependent on and formed by the cyclic fluctuating reservoir water levels. Therefore, any changes in the reservoir operations that would lead to a change in spatial distribution of the stopover habitat in the drawdown zone have the potential to alter patterns in neotropical migrant abundance and species richness.

6.3.4 Effects, Challenges, and Opportunities

The banding station methods used in this study allowed for a detailed assessment of neotropical migrants' utilization of stopover habitat. However, these methods are biased towards the primary habitats used by most neotropical migrants during fall migration and cannot be easily implemented in heavily flooded conditions or in certain low elevation habitats (e.g., grassland). While a considerable effort was made to monitor habitat-use across all habitat types using monitoring plots, the study had limited ability to track how species' habitat distributions were modified by reservoir operations. However, the evidence collected at plots and banding stations was sufficient to show that habitat-use can be influenced at lower elevations, and that the most important habitats remain highly functional for the majority of neotropical migrant songbirds.

6.4 MQ 4: Which neotropical migrants are most affected by reservoir operations?

Because reservoir-flooding makes habitats unavailable, neotropical fall migrants that use lower elevation habitats are more severely impacted by reservoir operations compared with species that use higher elevation habitats, such as the forest at Machete Island. In the study area, such low elevation habitats with high vulnerability to being flooded are unvegetated or grassland habitats, and to a lesser degree shrub savannah habitats, and usage at these low elevation habitats was shown to depend on reservoir operations (see evidence presented in Section 6.3).

The species that are most affected by reservoir operations are therefore those that prefer open grassland or unvegetated habitat including several obligate grassland species and some species associated with wetlands. Such species that we identify as being most affected by reservoir operations due to their preference for low elevation habitats include most sparrows (especially Savannah Sparrow, and to a lesser extent the Lincoln's Sparrow), Common Yellowthroat (the most common fall migrant), American Pipit, and Western Meadowlark – *Sturnella neglecta*. None of these species tend to move into forest habitats that remain upslope. Almost all these species are relatively common throughout their main geographic ranges (Campbell et al. 2001, Rodewald 2015). The Western Meadowlark is a more uncommon species in BC (Campbell et al. 2001, Cannings 2015); although common in its main geographic range (Davis and Lanyon 2008), but is found only in very small numbers in mountainous regions of BC so few individuals would be expected to be affected.

In higher elevation shrub and forest habitats, data from two banding stations at different elevations show different effects related to daily water level (Appendix S). At Machete Island, a more forested habitat at about 439 m, the daily water level at the site had no effect on abundance or species richness whereas at Airport Islands, a shrub habitat at about 437 m, daily water level at the site had a marginally negative effect on species richness but had no effect on abundance. This suggests that some shrub-using migrant species may be more affected than others. The most significant effects are likely felt by migrant species that prefer drier shrub habitat (e.g., Lazuli Bunting, Dark-eyed Junco – *Junco hyemalis*). However, the analysis of the neotropical migrant plasma metabolites revealed that the increased exposure of sites to reservoir waters did not compromise fattening rates of migrants using this habitat (Wagner et al. 2014).

6.5 MQ 5: Do reservoir operations affect the fattening rates of neotropical migrants using the drawdown zone during fall migration?

During migration, migrating songbirds need to stop on regular intervals to rest and refuel to be able to sustain energetically expensive nocturnal flight. However, not all stopover sites provide equal refuelling options and migrants' fattening rates depend on stopover habitat quality.

To address MQ 5, the fattening rates of neotropical migrants passing through the study area during the fall migration were assessed though plasma metabolite analysis, in which the residual plasma triglyceride is used to estimate fattening (refuelling) rate of migrants (Jenni-Eiermann and Jenni 1994, Williams et al. 1999, 2007). This allows one to assess stopover habitat quality from a single capture of a refuelling migrant (Guglielmo et al. 2005). The effect of reservoir operations was assessed by analysing plasma metabolite data for four species of neotropical migrant species (Yellow Warbler, Common Yellowthroat, Wilson's Warbler, and Orange-crowned Warbler) collected at Machete Island banding station (2008 to 2010). Despite those years having marked differences in water levels during fall migration season, no effect of water levels (daily reservoir level or year) on estimated fattening rate was found for any species, even after controlling for geographic origin of fall migrants, as determined by feather isotopes (Wagner et al. 2014). Expanding the scope of the study in 2011 and 2013 to new sites at different elevations (with different flooding frequencies), and adding two new species (Swainson's Thrush and Yellow-rumped Warbler), did not change these findings; no significant differences in estimated fattening rates for any species were found either among stations with different flooding frequencies or between years with different reservoir operations (CBA 2014).

In addition to the plasma metabolite analyses, a previous study by Green et al. (2011) concluded that the mass-gain of five species of neotropical migrants (American Redstart, Common Yellowthroat, Orange-crowned Warbler, Wilson's Warbler, and Yellow Warbler) captured at Machete Island banding station from 1998 to 2006 was not influenced by annual or weekly variation in reservoir water levels. In that study, the mass gain ranged from 0.32% to 0.98% of lean body mass per hour (Green et al. 2011); these values are within the range estimated for migrants at 13 other migration monitoring sites in Canada (0.14-1.09% lean body mass/hour; Dunn 2002) and above the estimated minimum threshold needed to cover daily energy use of wood-warblers at those sites (0.17-0.27% lean body mass/hour, eight species of wood-warblers; Dunn 2002). Moreover, Green et al. (2011) found that the density of migrants at the stopover site did not affect the rate of mass gain, suggesting that this site can provide foraging opportunities for migrants even when migrants habitat selection in the drawdown zone is restricted due to high waters. These findings suggest sufficient refuelling of migrants in riparian habitat within the drawdown zone which is not negatively affected by reservoir operations observed during the study period.

The study by Wagner et al. (2014) is one of the few that has looked at possible effects of human-caused manipulation of habitat on the physiological health of migrant songbirds. The fact that the migrants are able to gain mass at the rate sufficient to sustain migration and that this is not compromised by rising reservoir water confirms the importance of the reservoir drawdown habitat for providing foraging opportunities for neotropical migrant songbirds. The relative importance of Revelstoke Reach drawdown habitat is magnified due to the extreme scarcity of well vegetated riparian habitats along the impounded sections of the Columbia River in British Columbia.

6.5.1 Effects, Challenges, and Opportunities

The MQ was addressed using a robust methodology that uncovered no evidence for an impact of reservoir operations on fattening rates of migrants using riparian stopover habitat in the drawdown zone. One challenge in the Wagner analysis (Wagner et al. 2014) was a relatively low number of years and sites where metabolite observations were gathered; however, additional observations did not alter the conclusions (CBA 2014), and the results were consistent with an independent analysis conducted using alternate methods (Green et al. 2011).

If there is any impact of reservoir operations on fattening rates of certain migrant songbirds, we conclude that it must be a relatively small effect restricted to a few uncommon species that will be very challenging to detect. Given that fattening rates of common species sampled in the most important stopover habitats were consistently 'normal' regardless of reservoir operations, any minor effect of reservoir operations, should they exist for a few uncommon species, have negligible importance to the ecological function of Revelstoke Reach as migratory stop-over habitat.

6.6 MQ-6 Can operational adjustments be made to reduce impacts on neotropical migrants during fall migration or are mitigation measures required to minimize the loss of stopover habitat?

There are two potential related impacts of reservoir operations on neotropical migrant songbirds during the fall migration: (1) impacts to habitat availability and (2) impacts to habitat suitability. Habitat availability can be influenced via the inundation of habitat. As noted in Section 6.2 (MQ-2), most neotropical migrants utilize canopy habitat that is generally not inundated during fall migration. There are however a few species that might be influenced because they use near-ground habitats (e.g., Common Yellowthroat) or ground habitat (e.g., Savannah Sparrow), which in some cases can be inundated. However, most species that may have exposure to impacts also commonly use habitats at high elevations (e.g., Common Yellowthroat at Machete Island, or Savannah Sparrow outside the drawdown zone) so the impact is expected to be relatively small. Accordingly, in Section 6.3 (MQ-3) we found little evidence of impacts. We theorize that operational adjustments can be made to improve habitat availability of some neotropical migrants (especially lower elevation grassland habitat), but the evidence suggests that the benefit that can be achieved will be minimal. If alteration to reservoir operations are considered to achieve this goal, it can probably best be informed by considering vegetation mapping in the drawdown zone and cross-referencing this with migration timing (see Appendix G) for the subset of species that are most vulnerable based on knowledge generated on their habitat selection in the drawdown zone (see Section 6.2).

Regarding impacts of reservoir operations on habitat suitability, this study (see Section 6.5) found no evidence that reservoir operations (experienced during the study period) were affecting suitability of the most important stopover habitats. While operation adjustments can be made to improve suitability of lower elevation grassland habitat, this would benefit relatively small number of neotropical migrants. Moreover, since the high quality riparian stopover habitat is supported and maintained by the fluctuating reservoir water levels, operational adjustment designed to improve suitability of low elevation grassland habitats would have to consider potential impacts to this valuable riparian habitat so that it's function as high quality stopover habitat is not compromised (e.g., ingrowth of upland or conifer species).

6.6.1 Effects, Challenges, and Opportunities

As noted above, effect sizes of reservoir operations on migratory bird stop over habitat appear to be exceedingly small. Identifying meaningful ways to alter reservoir operations to benefit neotropical migrant songbirds will be very challenging.

6.7 MQ 8: Are the ongoing revegetation projects effective at improving utilizations of the treated habitat in the drawdown zone by neotropical migrants?

In the early years of the project (2010 to 2011), cottonwood stakes, and, to a lesser extent, other deciduous species, were planted in selected areas of Revelstoke Reach (Keefer and Moody 2010). Although other revegetation efforts occurred (sedge plantings) they were too small and inseparable from natural vegetation to be monitored for bird use, or to have any real benefit to neotropical migrant species. Therefore, to address this MQ, we focused on revegetation with cottonwood stakes.

Cottonwood stakes varied in survival rate and growth rate among treatment sites (12 Mile, 9 Mile, McKay Creek, 9 Mile point). For example, at the 12 Mile treatment area, cottonwood stakes had arguably the best growth and survival rate, and by the end of the study period provided more mature habitat than the other areas (Figure 12). Conversely, in areas with limited revegetation success, most stakes either did not survive (e.g., McKay Creek area) or experienced slower growth (e.g., 9 Mile area).

Figure 12: Cottonwood stakes at the 12 Mile site in August 2010 (left) and in August 2016 (right).

Among planted areas, the only significant difference in migrant abundance and species richness between treatment and control plots was on plots in the McKay Creek area (treatment plots had higher abundance and species richness; Appendix U**Error! Reference source not found.**).

Overall, there was no consistent change in abundance or species richness on treatment plots over time (2011 to 2016; Figure U-3 and Figure U-4, respectively). While there was an increase in abundance at the McKay Creek area (Figure U-6) and an increase in species richness at the

9 Mile area (Figure U-8), there was no significant improvement in abundance (Figure U-5) or species richness (Figure U-9) over time at 12 Mile - the site with best growth of cottonwood stakes.

The McKay Creek site was the only site with higher abundance on treated sites compared with untreated sites, and was the only site with a documented increase in abundance over time. This didn't provide strong support for efficacy of the treatment, however, because this site had the worst survival rate of planted saplings among all treated sites (almost complete treatment failure). It is possible that a legitimate side-effect of the treatment contributed to this result; for example, an increase in abundance due to the disturbance of the monotonous graminoid and addition of stakes (perches) caused by the treatment. However, that explanation is weak because the response was inconsistent among sites, and because it doesn't explain the increase in abundance over time. It is also possible that the utilization of these unsuccessful treatment plots at McKay Creek, was a particular response at this site driven by its close proximity to high-quality habitat (adjacent to highly utilized riparian forest habitat). It is also possible that the result at McKay Creek is simply an improbable random outcome.

For sites with more successful treatments, the relatively short time since implementation and the small size of treatment blocks and in some cases their location in proximity to alternative naturally existing shrubs or trees (e.g., some plots at the 12 Mile and the 9 Mile) likely all contributed to a lack of significant detectable response by neotropical migrants.

While the treatments as implemented were ineffective at improving habitat for migrating songbirds during the limited timeframe of the study (similar to the results from spring monitoring, Section 7.1), we believe that planting of cottonwood or other deciduous trees (e.g., willow, red-osier dogwood) has the potential to enhance habitat for neotropical migrants. As discussed in Section 6.2, the abundance and diversity of migrants was higher in tree and shrub habitats, specifically riparian forest habitats, than in grasslands. Moreover, pooling all surveys conducted on random plots during fall migration (Data Set #6), cottonwood was the most often recorded substrate utilized by neotropical migrants (29% of all birds were using cottonwood). Therefore, we believe that if planted in large enough areas and sufficient time is allowed for the cottonwood saplings to mature, these areas can become high quality habitat for migrating songbirds.

6.7.1 Effects, Challenges, and Opportunities

While there are marked differences in utilization of shrub/forest habitat compared to grassland habitat, multiple issues contributed to the lack of detectable response of migrants to the cottonwood treatments. Primarily, the timeframe of this study did not allow for the planted cottonwood stakes to reach an age when they would provide suitable cover or foraging substrate. The limited survival of cottonwood stakes at some sites and the small size of treatment blocks resulted in patches of established young cottonwoods which may not have been large enough or dense enough to affect migrants' utilization of these areas (at least at this age of the treatment). Moreover, treatment blocks where the response by migrants was expected to be strongest due to a dramatic potential for change in habitat structure (treatments in open grassland) had only low treatment success. Conversely, sites with higher treatment success (e.g., 12 Mile) tended to be in areas which already had some established shrubs/trees prior to the treatment and which, consequently, were already used by migrants utilizing tree/shrub canopy prior to the treatment.

6.8 MQ 9: Does the operation of Arrow Lakes Reservoir impact the availability or quality of stopover habitat in Revelstoke Reach for neotropical migrants?

The impact of reservoir operations on habitat availability is directly related to the distribution of habitat in the drawdown zone. Due to the bathymetry/topography of the drawdown zone study area in the ALR, and as is normally the case in most impounded valleys, lower elevation habitats cover more total area than the habitats positioned higher in the drawdown zone (Figure 13). In general, grassland is a dominant habitat at elevations below 437 m, shrub habitat becomes more widespread at elevations above 437 m and forested habitat becomes dominant above 439 m (Figure 13). Unvegetated habitat is present primarily below 437 m and permanent wetland habitat is present mostly at or below 438 m.

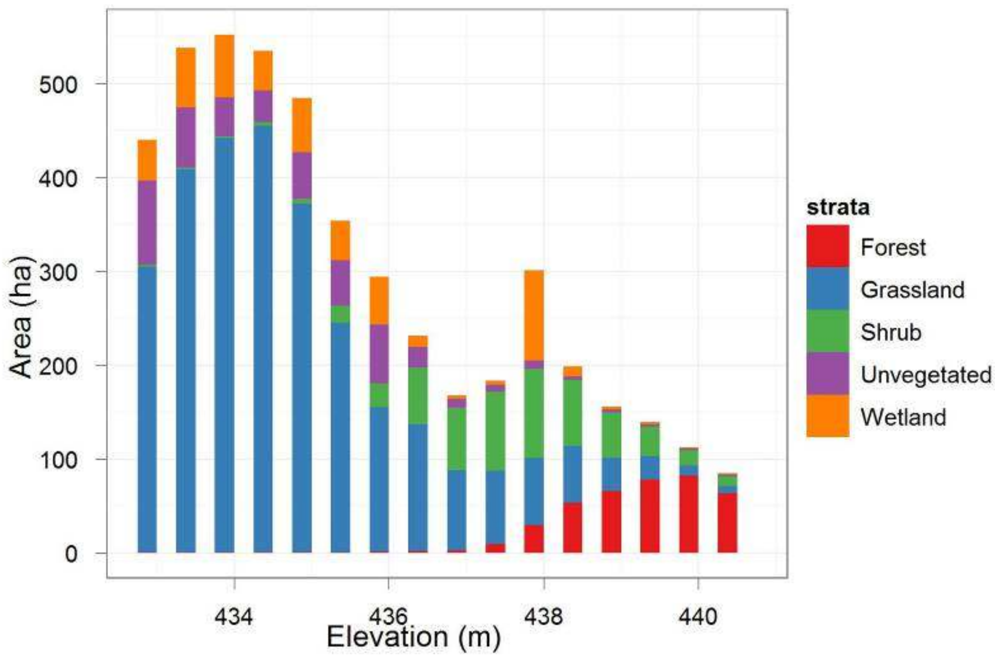


Figure 13: Total area of each habitat strata in the drawdown zone of Revelstoke Reach plotted in 0.5 m elevation bands.

At a finer level, the distribution of vegetation communities in the drawdown zone is also dependent on elevation. In total, mixed grassland is by far the most widely distributed habitat type in the drawdown zone and this type of grassland covers 37% of all area in the drawdown zone. The other important habitat types are shrub savannah (11%), sedge grassland (10%) and sparse grassland (8%). All the other habitat types cover less than 5% of the total area each (Appendix D). Both forest habitat types are distributed mostly above 438 m. Both shrub savannah and riparian shrub habitat types peak around 438 m. All five grassland habitat types are distributed predominantly below 438 m. The amount of area covered by each habitat type at different elevations in the drawdown zone is summarized in Figure V-1.

Due to the elevation gradient of the ALR drawdown zone (Figure 13), at the reservoir water level of 438 m, 79.2% of all mapped habitat in the drawdown zone study area is flooded. The amount of habitat lost due to the direct effect of flooding varies based on water levels and is different among habitat strata. For example, with the water level at 438 m, 93% of grassland habitat, 95% of unvegetated habitat, 77% of wetland habitat, 50% of shrub habitat and 4% of forested habitat is flooded. The effect of the reservoir water level on the availability of the habitat from different habitat types varies (Figure V-2). Reservoir operations have a clear effect upon the availability of stopover habitat as, at certain water levels, all grassland and most shrub habitats are flooded, precluding use by species that forage on the ground. Fortunately, there are relatively few species considered by this study that prefer grassland habitats, so impacts are lessened. Forest habitat (and to some extent shrub habitat), even when flooded, is not excluded as a stopover habitat as most of the tree and shrub canopy is above water. Results summarized in Section 6.3 show that forest habitat, even when flooded, still hosts neotropical migrants and their abundance and species richness is not significantly influenced by flooding.

The effect of reservoir operations on neotropical migrant habitat quality was primarily assessed by studying migrant physiology. Migrant fattening rates were compared among years with different reservoir levels and among habitats that experienced different degrees of flooding. No significant difference was found in fattening rates of four species of neotropical migrants among years with marked differences in reservoir operations (Wagner et al. 2014). In addition, no consistent effect of reservoir water levels (weekly or annual) was found on mass gain of five species of migrants in the drawdown zone (Green et al. 2011). Moreover, no significant difference was found in fattening rates of migrants between habitat that floods more frequently (and for a longer period of time) and habitat that floods less frequently and for a shorter period of time (CBA 2014).

The study of neotropical migrant fattening rates clearly shows that quality of shrub or forest habitat is not negatively affected by reservoir water levels. While reservoir operations seem to have little or no effect on habitat quality for birds that use shrub or forest habitats, birds which prefer using grassland habitats were not studied for physiological responses. As the lower elevation grasslands disappear with the rising reservoir levels, this precludes use of that habitat for fall migrants. Those birds simply are not present in these low elevation habitats as this habitat is not available or is unsuitable (Section 6.3). While the alpine habitats might be used in fall migration as a substitute for valley bottom grasslands, and this may alleviate some of the effects of unavailable grassland habitat, this theory remains untested.

Overall, the reservoir operations do not affect fattening rates of migrants using the most important stopover habitats in the drawdown zone (shrub and forest) and that the quality of these riparian sites is not negatively influenced by the reservoir operations experienced during the study period.

6.8.1 Effects, Challenges, and Opportunities

As evidenced by analyses of fattening rates of a few common neotropical migrants using the most important riparian stopover habitats (Section 6.5), the effect of reservoir operations on riparian stopover habitat quality for most migrants using the drawdown zone is probably very small, if it exists. For a small selection of grassland obligate species, the effects of reservoir operations on habitat quality (quality of grassland stopover habitat) may be more significant. However, because grassland species are relatively uncommon during the early parts of the fall migration season (when the water level is usually the highest) and a potential use of alpine habitat may serve as a substitute, the impact to these species is likely small.

7 MANAGMENT QUESTIONS – CLBMON-11B2

7.1 MQ-11B2-1 Are the revegetation and the wildlife physical works projects effective at enhancing wildlife habitat in the drawdown zone?

While revegetation with cottonwood stakes has the potential to improve stopover habitat by creating new, high quality riparian sites, very small scale of the treatments, low treatment success and short interval since implementation resulted in no increase in utilization of these treated areas by migrants during fall migration within the duration of this study (Section 6.2). In this section, only data collected during spring migration are considered.

Among various revegetation treatments that were attempted, only the cottonwood stakes had biological relevance to neotropical migrant songbirds, and neither of the two WPW projects (WPW15A, WPW6A) implemented during the course of this study were designed to maintain or enhance habitat for migrant songbirds. To address this MQ using data, we therefore focus on cottonwood stake monitoring.

Cottonwood stakes were planted in selected areas (12 Mile, 9 Mile, McKay Creek, 9 Mile point) of Revelstoke Reach in the early years of the CLBMON-11B2 project (Keefer and Moody 2010). Their survival rate and growth rate varied among different treatment areas. At the 12 Mile treatment area, cottonwood stakes had the best survival rate (Figure 12). In other areas with limited revegetation success most stakes either did not survive (e.g., McKay Creek area) or experienced slower growth (e.g., 9 Mile area).

The changes in abundance and species richness over time varied among sites (Figure W-3 and Figure W-4, respectively), but the observations made among treatment and control plots, and over the coarse of the study (e.g., as vegetation grew) did not validate or confirm efficacy of revegetation treatments. Overall, there was no significant difference in the cumulative annual abundance between treatment and control plots at any area (Appendix W) and neither abundance nor species richness exhibited an increasing trend at any of the treated areas (Appendix W**Error! Reference source not found.**).

In conclusion, there was no evidence that planting cottonwood stakes improved neotropical migrant use of the treated areas during the first six years following treatment. It is likely that the planted treatment sites were too small in size, or the treatment success was too low, and/or that more time is needed for trees to grow sufficiently to influence abundance and richness.

However, the cottonwood stake plantings do have potential for enhancing migrant bird habitat. As documented by analysis of random plot data, the neotropical migrant abundance and species richness increases with increasing vertical vegetation structure (Section 6.2), and both abundance and species richness were significantly higher in forest and shrub habitat compared to grassland habitat (Appendix O). In addition, 13% of all neotropical migrants recorded on random plots during spring migration (Data Set #7) were using cottonwood as a substrate, and cottonwood was the second most frequently used substrate (after willow). While some open habitat species may be negatively affected by the increased complexity of vegetation cover (e.g., America Pipit, Savannah Sparrow, Common Yellowthroat), most neotropical migrants should respond positively to the treatment, if sufficiently established. Based on what has been observed at sites with more mature cottonwoods, it is likely that benefits to songbirds will increase in the future as these plants mature.

Two years of spring monitoring were conducted at sedge planting sites in 2010 and 2011, but these treatments were not distinguishable from naturally occurring sedges, which are common, widespread, and used by very few neotropical migrants (e.g., American Pipit, Savannah Sparrow). Additionally, the area planted was too small to have any effect within the larger scale of Revelstoke Reach. Effectiveness monitoring was discontinued after 2011 as it became clear that sedge plantings would have no effect on migrant songbird habitat, and that monitoring effort was better spent on more relevant effort-limited monitoring tasks (e.g, Data Set #7 – see Section 4.7). It should also be noted that sedge treatments were not designed for migrant birds but for other purposes (Keefer and Moody 2011).

Effectiveness monitoring was also conducted for WPW 15A (and the previously proposed WPW 14) in Cartier Bay (Golder Associates 2009), with baseline surveys for spring migrants conducted in spring 2011 and 2016. Initial plans for the project held the potential to deepen the Cartier Bay pond, and the baseline monitoring was conducted primarily to characterize the suitability of the inundated shorelines (potential habitat loss) However, the WPW15A project (implemented in summer of 2016) was not designed to alter, enhance, or even maintain migrant songbird habitat, and did not appear to result in any relevant alterations to wildlife habitat of any form (Michal

Pavlik *personal observation*; see also Miller et al. *in preparation*). As such we can safely conclude WPW15A had no potential to benefit or affect migrant songbirds in any way during spring migration, and no additional monitoring was required.

7.1.1 Effects, Challenges, and Opportunities

This Management Question is difficult to answer with certainty for revegetation efforts due to the insufficient replication of suitably large successful revegetation treatments implemented during the course of the study. However, results from other components of this study (e.g., Section 6.2) strongly suggest that, if sufficiently large areas are planted and successful, revegetation with cottonwood stakes is realized, this should increase the wildlife habitat for to migrating songbirds. The absence of WPW projects designed to alter or enhance habitat for migrating songbirds, gives this MQ low relevance with respect to WPW projects.

7.2 MQ-11B2-2 If revegetation and the wildlife physical works projects enhance wildlife habitat in the drawdown zone, to what extent does the revegetation program and the wildlife physical works projects increase the productivity of habitat in the drawdown zone for wildlife?

This Management Question has no relevance to module 2 (CLBMON-11B2 was not measuring productivity of habitat). This MQ is addressed by CLBMON-11B1.

7.3 MQ-11B2-3 Are some methods or techniques more effective than others at enhancing wildlife habitat in the drawdown zone?

This Management Question is difficult to answer using an empirical data/analysis approach given that no treatments were empirically determined to be effective in this study (see Section 7.1). Of all the revegetation and WPW projects conducted during this study, revegetation with cottonwood stakes has the best potential to enhance wildlife habitat in the drawdown zone for migrating songbirds.

While WPWs could certainly be designed to improve habitat for spring migrants, any such WPW would need to assess effects on other values before being considered. It seems plausible that revegetation with trees (e.g., willow and cottonwood stakes) would improve open grassland habitat for spring migrants by increasing structural complexity of the site. However, due to fluctuation of reservoir water levels, only higher elevation sites can sustain quality forest habitat, and a lot of these areas already have some form of shrub/tree cover present. Raising some unproductive, low elevation areas to create islands and revegetating them would clearly improve attractiveness of these areas to migrating songbirds but may not be in line with the ALR management strategy. Planting a variety of native deciduous saplings (e.g., various willows, cottonwood, alder, red-osier dogwood, black twinberry) where such species are lacking will undoubtedly enhance suitability for a wide variety of migrant songbirds, but such revegetation would also need to be considerably more extensive in order to have any effect in the larger context of the Revelstoke reach study area.

8 LITERATURE

AXYS. 2002. Mica-Revelstoke-Keenleyside water use plan: breeding bird and migratory shorebird use of the Revelstoke wetlands. Report for Water Use Planning, BC Hydro, Burnaby, BC.

Bates, D., M. Maechler, and B. Bolker. 2011. Lme4: Linear mixed-effects models using S4 classes. R package version 0.999375-39. http://CRAN.R-project.org/package=lme4.

BC Hydro. 2007. Columbia River Project Water Use Plan, BC Hydro, Burnaby, BC.

Boulanger, J. 2005. Land birds in a high human use riparian zone: Revelstoke Reach wetlands. Columbia Basin Fish and Wildlife Compensation Program, Nelson, BC.

Boulanger, J., G. J. Woods, and J. Jarvis. 2002. Songbird use of four floodplain vegetation types in the Revelstoke Reach, Upper Arrow Reservoir, British Columbia, Canada. BC Hydro, Burnaby, BC

Breheny, P., and W. Burchett. 2017. Visualization of regression models using visreg. The R Journal 9:2, p 56-71.

Cameron, K. 2017. Tatlayoko Lake Bird Observatory – 2017 Annual Report. Unpublished report. 17pp + App.

Campbell, R. W., N. K. Dawe, I. McTaggart-Cowan, J. M. Cooper, G. W. Kaiser, and M. C. E. McNall. 1997. The Birds of British Columbia. Volume 3: Passerines, flycatchers through vireos. UBC Press, Vancouver, BC.

Campbell, R. W., N. K. Dawe, I. McTaggart-Cowan, J. M. Cooper, G. W. Kaiser, and M. C. E. McNall. 2001. The Birds of British Columbia. Volume 4: Passerines, warblers through finches. UBC Press, Vancouver, BC.

Cannings, R. J. 2015. Western Meadowlark *in* Davidson, P. J. A., R. J. Cannings, A. R. Couturier, D. Lepage, and C. M. Di Corrado (eds.). The Atlas of the Breeding Birds of British Columbia, 2008-2012. Bird Studies Canada. Delta, BC http://www.birdatlas.bc.ca/accounts/speciesaccount.jsp?sp=WEME&lang=en. Accessed September 20, 2019.

Carlisle, J. D., S. K. Skagen, B. E. Krus, C. van Ryper, K. L. Paxton, and J. F. Kelly. 2009. Landbird migration in the American West: recent progress and future research directions. Condor 111: 211-225.

Cooper Beauchesne and Associates Ltd [CBA]. 2010a. CLBMON-39: Arrow Lakes Reservoir neotropical migrant use of the drawdown zone, Year 2, 2009. BC Hydro Water Licence Requirements, Castlegar, BC.

Cooper Beauchesne and Associates Ltd [CBA]. 2010b. CLBMON-39: Arrow Lakes Reservoir neotropical migrant use of the drawdown zone: monitoring protocols, Year 3, 2010. BC Hydro Water Licence Requirements, Castlegar, BC.

Cooper Beauchesne and Associates Ltd [CBA]. 2012. CLBMON-39: Arrow Lakes Reservoir neotropical migrant use of the drawdown zone, Year 4, 2011. BC Hydro Water Licence Requirements, Castlegar, BC.

Cooper Beauchesne and Associates Ltd [CBA]. 2013. CLBMON-39: Arrow Lakes Reservoir neotropical migrant use of the drawdown zone: monitoring protocols, Year 6, 2013. BC Hydro Water Licence Requirements, Burnaby, BC.

Cooper Beauchesne and Associates Ltd [CBA]. 2014. CLBMON-39: Arrow Lakes Reservoir neotropical migrant use of the drawdown zone, Year 6, 2013. BC Hydro Water Licence Requirements, Burnaby, BC.

Cooper Beauchesne and Associates Ltd [CBA]. 2015. CLBMON-39: Arrow Lakes Reservoir neotropical migrant use of the drawdown zone, Year 7, 2014. BC Hydro Water Licence Requirements, Burnaby, BC.

Cooper Beauchesne and Associates Ltd [CBA]. 2016a. CLBMON11B-2. Arrow Lakes Reservoir: Revelstoke Reach spring songbird effectiveness monitoring. Monitoring protocols, Year 7, 2016. BC Hydro Water Licence Requirements, Burnaby, BC.

Cooper Beauchesne and Associates Ltd [CBA]. 2016b. CLBMON-40: Arrow Lakes Reservoir Shorebird and Waterbird Monitoring Program. Annual Report – Year 8, 2015. Unpublished report for BC Hydro Generation, Water Licence Requirements, Burnaby, BC. 41 pp. + Apps.

Cooper Beauchesne and Associates Ltd [CBA]. 2017. CLBMON-39: Arrow Lakes Reservoir neotropical migrant use of the drawdown zone: monitoring protocols, Year 10, 2017. BC Hydro Water Licence Requirements, Burnaby, BC.

Cooper Beauchesne and Associates Ltd [CBA]. 2018. CLBMON-39: Arrow Lakes Reservoir neotropical migrant use of the drawdown zone, Year 10, 2017. BC Hydro Water Licence Requirements, Burnaby, BC.

Davis, S. K., and W. E. Lanyon. 2008. Western Meadowlark *(Sturnella neglecta*), version 2.0. *In:* The Birds of North America (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bna.104.

DeGraaf, R. M., and J. H. Rappole. 1995. Neotropical migratory birds: natural history, distribution and population change. Cornell University Press, Ithaca, N.Y.

DeSante, D. F., and T. L. George. 1994. Population trends in the landbirds of western North America. *In* Avifaunal change in western North America. *Edited by* J. R. Jehl and N. K. Johnson. Studies in Avian Biology 15. pp. 173–190.

Dunn, E. H. 2002. A cross-Canada comparison of mass change in birds during migration stopover. Wilson Bulletin 114: 368–379.

Environment and Climate Change Canada [ECCC]. 2017. Birds protected under the Migratory Birds Convention Act. https://www.canada.ca/en/environment-climate-change/services/migratory-birds-legal-protection/convention-act.html. Accessed October 2019.

Green, D. J., and S. P. Quinlan. 2007. Evaluating the health of riparian habitats: water use decisions and breeding performance of Yellow Warblers in Revelstoke Reach, BC Columbia Basin Fish and Wildlife Compensation Program, Nelson, BC.

Green, D. J., M. W. Pennell, K. B. Loukes, and J. Jarvis. 2011. Reservoir water levels do not influence daily mass gain of warblers at a riparian stopover site. Journal of Field Ornithology 82:11-24.

Golder Associates. 2009. CLBWORKS-29A volume I: Arrow Lakes Reservoir Wildlife Physical Works feasibility study. BC Hydro Water Licence Requirements, Castlegar, BC.

Guglielmo, C. G., D. J. Cerasale, and C. Eldermire. 2005. A field validation of plasma metabolite profiling to assess refueling performance of migratory birds. Physiological and Biochemical Zoology 78(1): 116–125.

Jackman, S. 2017. Pscl: Classes and Methods for R Developed in the Political Science Computational Laboratory. United States Studies Centre, University of Sydney. Sydney, New South Wales, Australia. R package version 1.5.2. URL https://github.com/atahk/pscl/.

Jarvis, J., and J. G. Woods. 2002. Columbia River-Revelstoke migration monitoring station final banding report for 2001. BC Hydro Strategic Environmental Initiatives Program, Burnaby, BC.

Jenni-Eiermann, S., and L. Jenni. 1994. Plasma metabolite levels predict individual body mass changes in a small long-distance migrant, the Garden Warbler. Auk 111: 888–899.

Keefer, M., and R. Moody. 2010. Arrow Lakes Reservoir planting and monitoring plan for 2010, CLBWORKS-2. BC Hydro Water Licence Requirements, Castlegar, BC.

Korman, J. 2002. Simulating the response of aquatic and riparian productivity to reservoir operations: description of the vegetation and littoral components of BC Hydro's integrated response model (IRM). BC Hydro Water Licence Requirements, Castlegar, BC.

Mackenzie Nature Observatory [MNO]. 2017. Mugaha Marsh Banding Station - 2017 Annual Birding Report. Unpublished report. 35pp + App.

Manning Cooper and Associates [MCA]. 2003. Columbia River Water Use Plan nesting bird summary. Prepared for BC Hydro, Burnaby, BC.

Martin, T.E., and D.M. Finch (Editors). 1995. Ecology and management of neotropical migratory birds: A synthesis and review of critical issues. Oxford University Press. 512 pp.

Martin, T. G., I. Chades, P. Arcese, P. P. Marra, H. P. Possingham, and D. R. Norris. 2007. Optimal conservation of migratory species. PloS ONE 2: pe751.

Meidinger, D., and J. Pojar. 1991. Ecosystems of British Columbia. BC Ministry of Forests, Victoria, BC.

Miller, M. T., D. B. Adama, and V. C. Hawkes. *In Preparation*. CLBMON-11B4 Monitoring Wetland and Riparian Habitat in Revelstoke Reach in Response to Wildlife Physical Works. Annual Report – 2018.

Moody, A. I. 2002. Long-term monitoring of vegetation expansion and trials in the dust control treatment areas of Revelstoke Reach–Upper Arrow Reservoir. Report prepared by AIM Ecological Consultants for BC Hydro Strategic Environmental Initiatives Program.

North American Banding Council [NABC]. 2001. The North American banders' study guide. Publication Committee. 68pp.

Ogden, L. J. E., K. Martin, and T. D. Williams. 2013. Elevational differences in estimated fattening rates suggest that high-elevation sites are high-quality habitats for fall migrants. Auk 130: 98-106.

R Core Team. 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Rodewald, P. (Editor). 2015. The Birds of North America: https://birdsna.org. Cornell Laboratory of Ornithology, Ithaca, NY.

Sherry, T. W., and R. T. Holmes. 1996. Winter habitat quality, population limitation, and conservation of neotropical-Nearctic migrant birds. Ecology 77: 36–48. DOI: 10.2307/2265652.

Smith, H., J. McCracken, D. Shepherd, and P. Velez. 1999. The mist netter's bird safety handbook. The Institute for Bird Populations. 87pp.

Terborgh, J. 1989. Where have all the birds gone? Princeton University Press, Princeton, N.J.

Tremblay, E. M. 1993. Use of the Upper Arrow Lakes Reservoir at Revelstoke, BC by waterfowl and other waterbirds. British Columbia Birds 3: 3–12.

Venables, W. N., and B. D. Ripley. 2002. Modern Applied Statistics with S. Fourth Edition. Springer, New York. ISBN 0-387-95457-0.

Wagner, D. N., D. J. Green, M. Pavlik, J. M. Cooper, and T. D. Williams. 2014. Physiological assessment of the effects of changing water levels associated with reservoir management on fattening rates of neotropical migrants at a stopover site. Conservation Physiology Vol. 2, Issue 1. https://doi.org/10.1093/conphys/cou017.

Walker, B. G., P. D. Boersma, and J. C. Wingfield. 2005. Field endocrinology and conservation biology. Integrative and Comparative Biology 45: 12-18.

Williams, T. D., C. G. Guglielmo, O. Egeler, and C. J. Martyniuk. 1999. Plasma lipid metabolites provide information on mass change over several days in captive western sandpipers. Auk 116: 994-1000.

Williams, T. D., N. Warnock, J. Y. Takekawa, and M. A. Bishop. 2007. Flyway-Scale Variation in Plasma Triglyceride Levels as an Index of Refueling Rate in Spring-Migrating Western Sandpipers (*Calidris Mauri*). Auk 124, 886–897.

Wickham, H. 2016. ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag, New York, USA.

U.S. Fish & Wildlife Service. 2011. *Neotropical Migratory Bird Conservation Act*. http://www.fws.gov/birdhabitat/Grants/NMBCA/BirdList.shtm [accessed November 20, 2017].

Zeileis, A., C. Kleiber, and S. Jackman. 2008. Regression Models for Count Data in R. Journal of Statistical Software 27(8).http://www.jstatsoft.org/v27/i08/.

9 APPENDICES

Appendix A. CLBMON-39 constant effort mist netting and migrant physiology monitoring sites (DDZ = drawdown zone).

Site	Within DDZ?	Mean Elevation (m)	Description	Comments
Machete Island	Yes	439	Large riparian site	Willow dominated shrubby habitat on the edge of riparian cottonwood forest. Other common shrub species at site are red-osier dogwood, black twinberry, alder, and snowberry.
Rob's Willows	Yes	438	Large riparian site	Willow dominated shrubby vegetation. Compared to Machete Island, this site is at lower elevation in more open habitat, and shrubs and trees, on average, are lower in height and more sparsely distributed.
Airport Islands	Yes	437	Small riparian site	Willow dominated open shrubby site with some cottonwood mixed in. This site is at a lower elevation (floods more often and for longer period) and is fairly isolated from other suitable shrub or forest habitat (patches of shrubs in the middle of grassy flats).
Jordan River	No	475	Control outside of the drawdown zone	Shrubby site near Jordan River, dominated by willow and red-osier dogwood, but upland species are also present in area. Site is positioned well outside of the drawdown zone.
Cartier Point	No	441	Control outside of the drawdown zone	Cottonwood and birch dominated site with extensive bracken fern and thimbleberry understory. Some nets positioned on the edge of the drawdown zone (shrubby cottonwood outlining the high-water mark).

Appendix B. Survey effort at the five banding stations in Revelstoke Reach during CLBMON-39 monitoring.

Sampling frequency	Station	Year	No. of survey days	No. of nets per survey		No. of net-hours per survey		No. of net-hours
				Mean	SD	Mean	SD	
Daily	Machete Island	2008*	49	11.6	0.93	61.6	15.20	3018.5
		2009*	51	13.0	1.85	71.0	19.39	3623.0
		2010*	47	13.0	2.33	67.2	24.59	3159.5
		2015	40	12.2	1.89	57.8	25.20	2311.5
		2016	44	11.7	2.45	63.6	18.77	2800.0
		2017	35	10.9	2.76	59.3	18.69	2076.0
Weekly	Machete Island	2011	7	9.1	2.73	46.9	20.91	328.3
		2012	8	11.4	3.78	64.2	23.08	513.5
		2013	14	12.9	0.53	64.9	22.75	908.8
		2014	13	12.8	0.38	68.5	15.07	890.3
	Airport Islands	2011	6	8.2	2.04	44.5	13.65	266.8
		2012	9	8.2	0.97	45.2	7.57	406.8
		2013	14	9.0	0.00	45.0	12.77	629.5
		2014	8	8.3	1.39	47.1	8.52	376.5
		2015	7	8.0	0.82	40.4	10.38	283.0
		2016	7	8.6	0.79	50.3	4.81	352.0
		2017	7	6.9	2.48	31.5	17.60	220.8
	Jordan River	2011	9	6.8	0.97	36.9	6.85	332.5
		2012	13	9.5	0.88	52.8	9.22	687.0
		2013	15	10.0	0.00	53.7	8.96	805.0
		2014	9	10.0	0.00	58.1	4.97	522.5
		2015	7	6.7	0.49	37.9	3.98	265.5
		2016	8	6.8	0.71	36.3	12.28	290.3
		2017	7	7.0	0.00	39.3	5.88	274.8
	Cartier Point	2011	8	7.5	2.00	41.1	11.19	329.0
		2012	7	6.9	1.86	37.0	8.02	258.8
	Rob's Willows	2011	7	8.7	2.21	43.1	18.22	302.0
		2012	6	8.2	0.41	46.3	5.33	277.5

*Only surveys conducted in August and September are included

Appendix C. Stratification of CLBMON-39 permanent plots and number of plots within each habitat stratum and elevation band (DDZ = drawdown zone).

Strata	Above DDZ (m)			In DDZ (m)									Total
	≥ 442	442–441	441–440	440–439	439–438	438–437	437–436	436–435	435–434	434–433	433–432	432–431	
Forest	8	5	3	10	4	4	-	-	-	-	-	-	34
Shrub	4	-	5	-	7	8	5	-	-	-	-	-	29
Grassland	2	2	-	2	7	2	4	4	3	2	-	-	28
Unvegetated	1	-	-	-	-	-	-	-	1	2	1	2	7
Total	15	7	8	12	18	14	9	4	4	4	1	2	98

Appendix D. Revelstoke Reach habitat types (CBA 2016b).

Strata	Code	Habitat Type	% DDZ	Description
Channel	TH	Channel	2.9	The Columbia River channel and gravel bars
Forest	RF	Riparian	3.0	Riparian forest with cottonwoods and shrubs, with variable conifer component
	UF	Upland forest	5.1	Upland conifer and mixed forest
Grassland	EG	Equisetum grassland	1.9	Grasslands with a high amount of scouring rush
	MG	Mixed grassland	37.3	Default grassland habitat type
	RC	Reed canary grass	3.8	Grasslands dominated by thick reed canary grass
	SG	Sedge grassland	9.6	Grasslands with a high sedge content
	PG	Sparse grassland	8.0	Grasslands with relatively sparse cover; often low elevation, just above unvegetated habitat
Shrub	SR	Riparian shrub	0.8	Riparian shrub. These habitats are found along creeks, and near the mouths of creeks on alluvial fans
	SH	Shrub savannah	10.5	Shrub savannah with low shrubs of variable density (grassland with willow patches)
Steep bank	SB	Sand bank	0.1	Steep sand banks with variable amounts of vegetation
Unvegetated	CR	Coarse rocks	<0.1	Loose rocks with low amounts of grass or shrub or tree cover
	GR	Gravel	3.4	Gravel habitat with low amounts of grass or shrub or tree cover
	RB	Rocky bank	1.0	Steep bank of loose rocks or talus with variable amounts of vegetation
	SA	Sand	1.5	Sand habitat with low amounts of grass or shrub or tree cover
	SI	Silt	0.5	Unvegetated low elevation habitat comprised of silt and other fine deposits
	BE	Steep bedrock	0.1	Steep bank of bedrock, with variable amounts of vegetation
Urban	UR	Urban	<0.1	Residential or industrial areas including pavement
Wetland	BR	Bulrush	0.3	Marsh area with abundant patches of bulrush
	CT	Cattail	0.1	Marsh area with abundant cattail growth
	CK	Creek	0.3	Gravel/rocky creek channel or estuary
	BF	Floating bog	0.1	Floating peat bog that provides dry floating islands
	LD	Low elevation draw	4.0	Muddy/clay depression or channel with variable amount of sedge and or grass
	PO	Pond	4.1	Marsh or pond with variable amount of submergent vegetation
	BS	Submerged buoyant bog	0.1	Peat bog that rises with water, but is slightly submerged when water is high
	SW	Swamp	0.3	Complex swamp habitat with shrubs, beaver dams, and skunk cabbage
	WS	Water sedge	0.6	Marsh area with abundant sedge growth
	WM	Wet meadow	0.6	Sedge, grass, seasonally flooded area with depressions

Appendix E. Neotropical migrant songbirds detected in Revelstoke Reach during CLBMON-39 surveys (fall) and CLBMON-11B2 surveys (spring) in 2008 to 2017.

Introduction: This summary is provided to list all neotropical migrant species detected in Revelstoke Reach in spring and fall during the entire study period.

Dataset: Dataset #1 was used for this summary. This dataset contains presence/absence records of neotropical migrants from all components and all years of both CLBMON-39 (fall) and CLBMON-11B2 (spring) study.

Analysis: All years were pooled together, CLBMON-11B2 data was used for the spring period, CLBMON-39 data was used for the fall period, presence/absence only.

Results: During fall migration, 73 species of neotropical migrants were recorded in Revelstoke Reach. Pooling all years, Common Yellowthroat was the most abundant species (captured into mist nets), followed by Yellow-rumped Warbler, Traill's Flycatcher, American Redstart, and Yellow Warbler.

In spring, 65 species of neotropical migrants were recorded. American Pipit was the most frequently recorded species in spring, followed by Yellow-rumped Warbler, American Robin, Tree Swallow, and Savannah Sparrow.

Table E-1: Neotropical migrants detected in Revelstoke Reach during the spring (CLBMON-11B2) and fall (CLBMON-39) migration period.

Species Code	Common Name	Scientific Name	Spring	Fall
OSFL	Olive-sided Flycatcher	*Contopus cooperi*	x	x
WEWP	Western Wood-pewee	*Contopus sordidulus*	x	x
ALFL	Alder Flycatcher	*Empidonax alnorum*	x	x
TRFL	Traill's Flycatcher	*Empidonax alnorum/traillii*		x
WIFL	Willow Flycatcher	*Empidonax traillii*	x	x
LEFL	Least Flycatcher	*Empidonax minimus*	x	x
HAFL	Hammond's Flycatcher	*Empidonax hammondii*	x	x
DUFL	Dusky Flycatcher	*Empidonax oberholseri*	x	x
PSFL	Pacific-slope Flycatcher	*Empidonax difficilis*		x
UEFL	Unidentified Empidonax Flycatcher	*Empidonax* (sp)		x
SAPH	Say's Phoebe	*Sayornis saya*	x	
EAKI	Eastern Kingbird	*Tyrannus tyrannus*	x	x
UNFL	Unidentified Flycatcher	Tyrannidae		x
CAVI	Cassin's Vireo	*Vireo cassinii*	x	x
WAVI	Warbling Vireo	*Vireo gilvus*	x	x
REVI	Red-eyed Vireo	*Vireo olivaceus*	x	x
TRES	Tree Swallow	*Tachycineta bicolor*	x	x
VGSW	Violet-green Swallow	*Tachycineta thalassina*	x	
NRWS	Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	x	x
BANS	Bank Swallow	*Riparia riparia*	x	x
CLSW	Cliff Swallow	*Petrochelidon pyrrhonota*	x	x
BARS	Barn Swallow	*Hirundo rustica*	x	x
UNSW	Unidentified Swallow	Hirundinidae	x	x
HOWR	House Wren	*Troglodytes aedon*		x
MAWR	Marsh Wren	*Cistothorus palustris*	x	x
GCKI	Golden-crowned Kinglet	*Regulus satrapa*	x	x
RCKI	Ruby-crowned Kinglet	*Regulus calendula*	x	x
MOBL	Mountain Bluebird	*Sialia currucoides*	x	
TOSO	Townsend's Solitaire	*Myadestes townsendi*	x	x
VEER	Veery	*Catharus fuscescens*	x	x
SWTH	Swainson's Thrush	*Catharus ustulatus*	x	x
HETH	Hermit Thrush	*Catharus guttatus*	x	x
AMRO	American Robin	*Turdus migratorius*	x	x
GRCA	Gray Catbird	*Dumetella carolinensis*	x	x
AMPI	American Pipit	*Anthus rubescens*	x	x
CEDW	Cedar Waxwing	*Bombycilla cedrorum*	x	x
TEWA	Tennessee Warbler	*Oreothlypis peregrina*	x	x
OCWA	Orange-crowned Warbler	*Oreothlypis celata*	x	x
NAWA	Nashville Warbler	*Oreothlypis ruficapilla*	x	x
YWAR	Yellow Warbler	*Setophaga petechia*	x	x
CSWA	Chestnut-sided Warbler	*Setophaga pensylvanica*		x
MAWA	Magnolia Warbler	*Setophaga magnolia*		x
YRWA	Yellow-rumped Warbler	*Setophaga coronata*	x	x
MYWA	Myrtle Warbler	*Setophaga coronata*	x	x

Species Code	Common Name	Scientific Name	Spring	Fall
AUWA	Audubon's Warbler	*Setophaga coronata auduboni*	x	x
TOWA	Townsend's Warbler	*Setophaga townsendi*	x	x
BLPW	Blackpoll Warbler	*Setophaga striata*		x
BAWW	Black-and-white Warbler	*Mniotilta varia*	x	x
AMRE	American Redstart	*Setophaga ruticilla*	x	x
NOWA	Northern Waterthrush	*Parkesia noveboracensis*	x	x
MOWA	Mourning Warbler	*Geothlypis philadelphia*		x
MGWA	MacGillivray's Warbler	*Geothlypis tolmiei*	x	x
COYE	Common Yellowthroat	*Geothlypis trichas*	x	x
WIWA	Wilson's Warbler	*Cardellina pusilla*	x	x
UNWA	Unidentified Warbler	Parulidae	x	x
CHSP	Chipping Sparrow	*Spizella passerina*	x	x
CCSP	Clay-colored Sparrow	*Spizella pallida*	x	x
VESP	Vesper Sparrow	*Pooecetes gramineus*	x	x
LASP	Lark Sparrow	*Chondestes grammacus*	x	
SAVS	Savannah Sparrow	*Passerculus sandwichensis*	x	x
FOSP	Fox Sparrow	*Passerella iliaca*		x
SOSP	Song Sparrow	*Melospiza melodia*	x	x
LISP	Lincoln's Sparrow	*Melospiza lincolnii*	x	x
SWSP	Swamp Sparrow	*Melospiza georgiana*		x
WCSP	White-crowned Sparrow	*Zonotrichia leucophrys*	x	x
GCSP	Golden-crowned Sparrow	*Zonotrichia atricapilla*	x	
DEJU	Dark-eyed Junco	*Junco hyemalis*	x	x
ORJU	Oregon Junco	*Junco hyemalis oregonus*		x
UNSP	Unidentified Sparrow	Passerellidae	x	x
WETA	Western Tanager	*Piranga ludoviciana*	x	x
BHGR	Black-headed Grosbeak	*Pheucticus melanocephalus*	x	x
LAZB	Lazuli Bunting	*Passerina amoena*	x	x
BOBO	Bobolink	*Dolichonyx oryzivorus*	x	
RWBL	Red-winged Blackbird	*Agelaius phoeniceus*	x	x
WEME	Western Meadowlark	*Sturnella neglecta*	x	x
YHBL	Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	x	x
BRBL	Brewer's Blackbird	*Euphagus cyanocephalus*	x	x
BHCO	Brown-headed Cowbird	*Molothrus ater*	x	x
UNBL	Unidentified Blackbird	Icteridae	x	x
BUOR	Bullock's Oriole	*Icterus bullockii*	x	x
PISI	Pine Siskin	*Spinus pinus*	x	x
AMGO	American Goldfinch	*Spinus tristis*	x	x
UNSO	Unidentified Songbird	Passeri (cl)	x	x

Appendix F. Assessing seasonal variation in abundance and species richness of neotropical migrants during fall migration – analysis of capture records.

Introduction: This analysis considered capture rates at banding stations and was performed to investigate within-season variation in neotropical migrant abundance and species richness in the Revelstoke Reach during the fall migration, and to explore how within-season migratory activity varied among years.

Dataset: This analysis was conducted using a subset of dataset #2, which contained capture-recapture records (n=21,088) of 17,656 individuals of 57 species collected at Machete Island banding station during ten years of monitoring. In this dataset, Alder and Willow Flycatchers were pooled into one taxon – Traill's Flycatcher and only records of newly captured and recaptured birds were included. Same-day recaptures of previously banded/recaptured individuals were excluded. Dataset #2 was subset to only include years with daily monitoring (six years; Appendix B). This dataset contained records (n=18,656) of 15,428 individuals of 57 species of neotropical migrants.

Analysis: Data from all 10 years of monitoring were used to describe the overall pattern of neotropical migrant abundance and species richness during the fall migration. Daily capture rate and number of birds captured per net-hour (net-hour = one 12-m net in operation for one hour) was used as a measure of daily abundance. Daily species richness was measured as the number of neotropical migrant species captured each day. Pooled data from 10 years were plotted using a Loess smoother in the ggplot2 package for R (Wickham 2016).

The annual variation in the patterns of seasonal abundance and species richness were assessed using dataset #2A. Data were plotted using a Loess smoothing function from the ggplot2 package for R (Wickham 2016).

Results: The overall seasonal variation in neotropical migrant abundance is provided in Figure 3 and the overall seasonal variation in neotropical migrant species richness is provided in **Error! Reference source not found.**. Variation in seasonal abundance and species richness among years is plotted in Figure F-1 and Figure F-2, respectively.

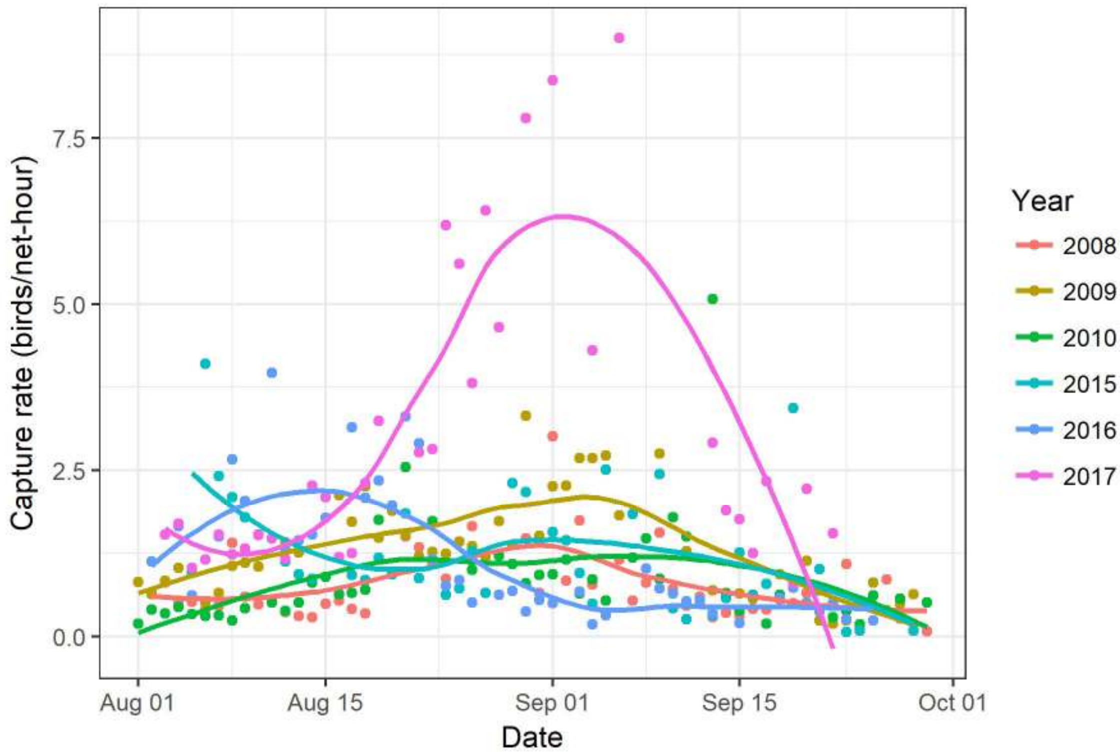


Figure F-1: Annual variation in daily capture rate of neotropical migrants at Machete Island banding station in years with daily monitoring (2008 to 2010 and 2015 to 2017).

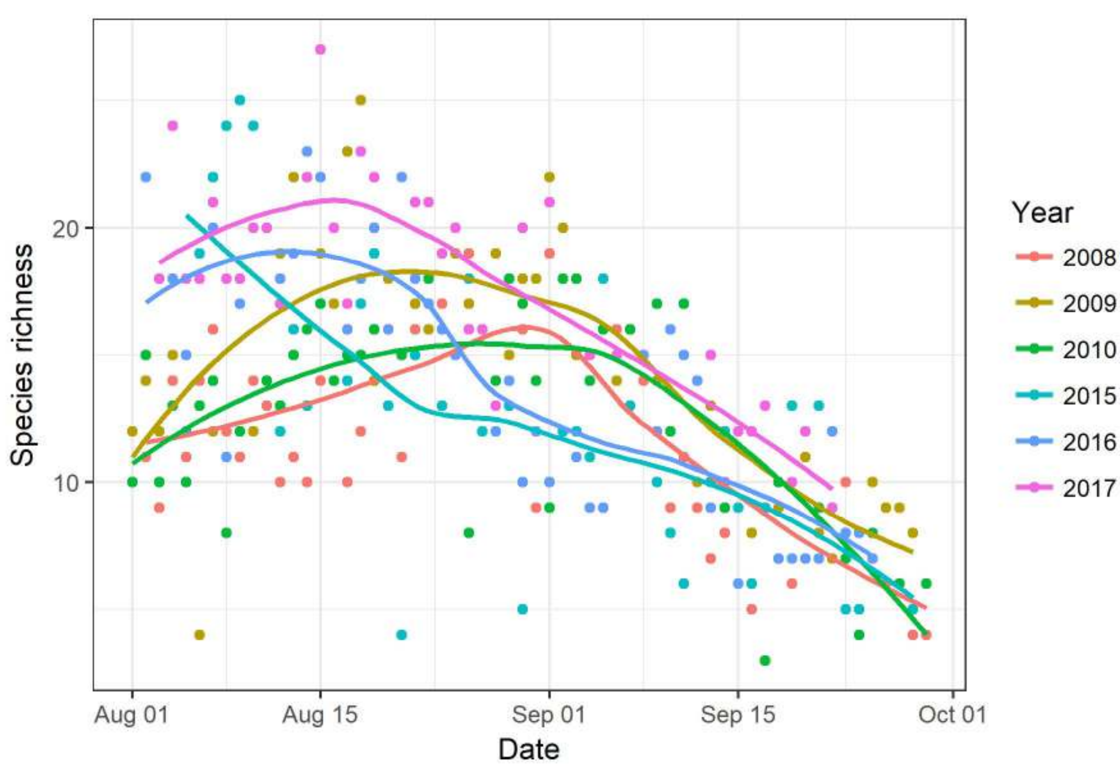


Figure F-2: Annual variation in daily species richness of neotropical migrants at Machete Island banding station in years with daily monitoring (2008 to 2010 and 2015 to 2017).

Comments: The robust sample size used in these two analyses allowed for description of the seasonal pattern of abundance and species richness of neotropical migrants in Revelstoke Reach in great detail. Thus, this description is representative of migrant presence in Revelstoke Reach.

Appendix G. Assessing seasonal abundance of neotropical migrants in Revelstoke Reach during fall migration – analysis of capture records and plot monitoring records.

Introduction: This analysis considered all records of neotropical migrants and was conducted to investigate the seasonal distribution of different species of migrants in Revelstoke Reach during fall migration.

Dataset: This analysis used dataset #3, which contained pooled data from all components of the CLBMON-39 study (data from all banding stations as well as data from permanent, random and effectiveness monitoring plot surveys). Only neotropical migrants identified to species were included in this dataset except for Traill's Flycatcher (unidentified Willow or Alder Flycatcher). For banding data, only records of newly captured and recaptured birds were included, same day recaptures of previously banded/recaptured individuals were excluded. For plot survey data, observations of birds recorded on plot, off plot and overhead were all included. During the ten years of monitoring, 37,543 bird records (of birds identified to species) of 73 neotropical migrant species were documented in Revelstoke Reach.

Analysis: For this analysis, data from all years and all components were pooled together and plotted using the ggplot2 package for R (Wickham 2016).

Results: The resulting overview of seasonal distribution of neotropical migrants in Revelstoke Reach is provided in Figure G-1.

Comments: The robust sample size used for this analysis allowed for description of the seasonal distribution of species of neotropical migrants in Revelstoke Reach very accurately. While capture-recapture data provided an accurate estimate of relative abundance, the inclusion of observation data collected at permanent, random, and effectiveness monitoring plot surveys allowed for the description of seasonal abundance of species not regularly captured in mist nets (e.g., swallows, American Pipit). Thanks to the large sample size and 10-year period of this study, the description here is likely accurate and representative of the seasonal abundance of neotropical migrants in Revelstoke Reach.

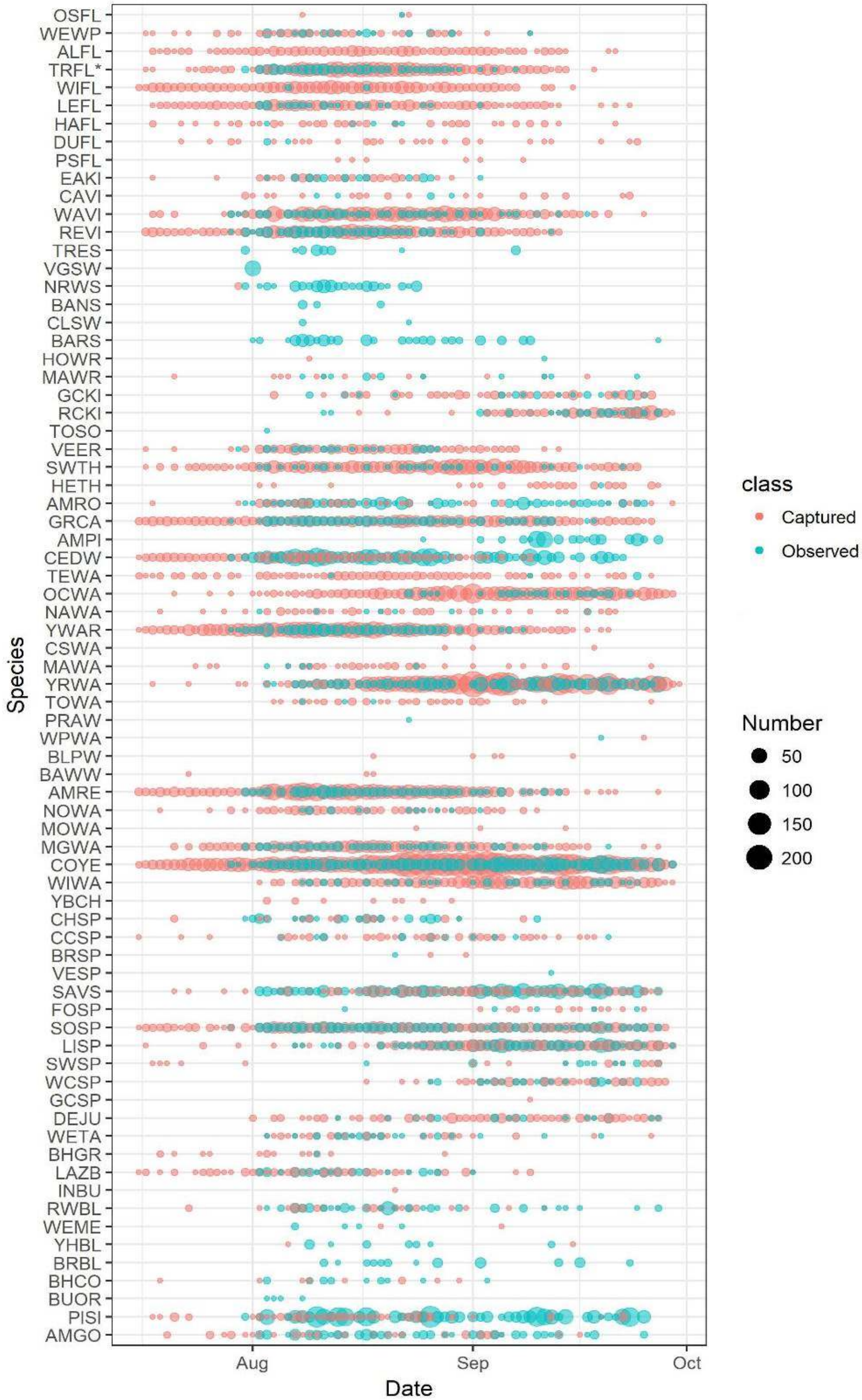


Figure G-1: Seasonal abundance of neotropical fall migrants recorded in fall at Revelstoke Reach from 2008 to 2017. Captured = captured in mist nets at all banding stations, Observed = recorded during permanent, random, and effectiveness monitoring plot surveys, Number = cumulative number of birds observed or captured. *TRFL = records of Willow and/or Alder Flycatcher not identified to species. Species codes are defined in Table E-1.

.

Appendix H. Assessing annual variation in abundance and species richness of captured neotropical migrants in Revelstoke Reach during the fall.

Introduction: This analysis was conducted to assess annual differences in abundance and species richness of neotropical migrants in the Revelstoke Reach during fall migration.

Dataset: Among-year variation in neotropical migrant abundance, and species richness, was examined using 4 subsets taken from Dataset #4 (see also Appendix B):

1. Daily Machete Island banding station (2008, 2009, 2010, 2015, 2016, 2017),
2. Weekly Machete Island banding station (2011, 2012, 2013, 2014),
3. Airport Island band station (2011 to 2017), and
4. Jordan River banding station (2011 to 2017).

Only newly captured birds were included, and Alder and Willow Flycatchers were combined into one taxon (Traill's Flycatcher).

During ten years of monitoring at Machete Island banding station, 17,656 individual birds of 57 species were newly captured. At Airport Islands, 920 individual birds of 30 species were newly captured and at Jordan River 2,246 individual birds of 39 species were newly captured. In total, 20,822 individuals of 60 species were captured in mist nets during the course of the study.

Analysis:
For each of the four data subsets, the difference in the number of newly captured birds among years was examined using a chi-square goodness-of-fit test (R function "*chisq.test*"; R Core Team 2019). For tests examining variation in abundance, the expected frequencies were corrected for survey effort. For tests examining variation in species richness, the expected frequencies for survey effort were not corrected, because all four groups of surveys were conducted during the same migration period and at least once a week. While increased effort (more nets open or more days) may (to some extent) increase the overall number of species detected, this relationship is diminishing (non-linear).
Annual variation in abundance of the 10 most frequent species was also assessed using data from Machete Island banding station (all years combined) and a chi-square goodness-of-fit test with equal expected frequencies corrected for survey effort.
The ggplot2 package for R (Wickham 2016) was used to visualize the data.

Results: The overall number of newly captured birds, capture rate, and overall species richness in each year for the three stations is presented in Table H-1.

Table H-1: Number of newly captured birds (N), capture rate (CR), species richness (R), and number of net-hours at the three banding stations in Revelstoke Reach during CLBMON-39 monitoring.

Year	Machete Island - daily				Machete Island - weekly				Airport Islands				Jordan River			
	N	CR	R	Net-hours	N	CR	R	Net-hours	N	CR	R	Net-hours	N	CR	R	Net-hours
2008	1751	0.58	43	3018.5	.	.	.	.	.	.	.	.	.	.	.	.
2009	3238	0.89	47	3623	.	.	.	.	.	.	.	.	.	.	.	.
2010	1866	0.59	45	3159.5	.	.	.	.	.	.	.	.	.	.	.	.
2011	.	.	.	.	240	0.73	30	328.25	181	0.68	14	266.8	211	0.64	29	332.5
2012	.	.	.	.	307	0.60	27	513.5	99	0.24	10	406.8	470	0.68	34	687
2013	.	.	.	.	972	1.07	34	908.75	194	0.31	13	629.5	487	0.60	33	805
2014	.	.	.	.	709	0.80	33	890.25	132	0.35	14	376.5	331	0.63	28	522.5
2015	1927	0.83	47	2311.5	.	.	.	.	108	0.38	14	283	215	0.81	29	265.5
2016	2239	0.80	49	2800	.	.	.	.	78	0.22	13	352	196	0.68	25	290.3

2017	4407	2.12	44	2076	.	.	.	.	128	0.58	14	220.8	336	1.22	26	274.8

Corrected for uneven survey effort among years, the total number of newly captured birds varied significantly among years at all three stations ($p < 0.001$ in all cases; Table H-2). However, species richness did not significantly differ among years at any station ($p > 0.05$ in all cases, Table H-2).

Table H-2: Inter-annual differences in the number of newly captured birds (corrected for survey effort) and species richness at Machete Island, Airport Islands, and Jordan River (Chi-square goodness-of-fit test; *** = p < 0.001, ** = p < 0.01, * = p < 0.05, ns = p > 0.05).

Station	Number Newly Captured			Species Richness		
	χ^2	df	p	χ^2	df	p
Machete Island - daily	4132.7	5	***	0.5	5	ns (0.99)
Machete Island - weekly	99	3	***	1.0	3	ns (0.81)
Airport Islands	142.8	6	***	1.0	6	ns (0.99)
Jordan River	126.6	6	***	2.3	6	ns (0.89)

To assess the variation in abundance of different species in Revelstoke Reach during 10 years of monitoring, data was analyzed from the three banding stations. At each of the three stations there were marked differences in abundance of different species among years (Table H-3, Table H-4, Table H-5). Pooling data from all three banding stations (21,349 individual birds of 60 species), Common Yellowthroat was the most frequently recorded species (21.2% of all observations), followed by Yellow-rumped Warbler (14.1%), Traill's Flycatcher (7.3%), American Redstart (6.2%), Yellow Warbler (5.8%), Orange-crowned Warbler (5.7%), Swainson's Thrush (5.0%), Warbling Vireo (5.0%), Wilson's Warbler (3.4%), and Red-eyed Vireo (3.0%).

At Machete Island banding station, the annual abundance of the 10 most frequently captured species varied significantly among years (Table H-3, Table H-6).To investigate annual differences in the relative abundance of all other species, annual capture rate of different species at all three banding stations was plotted (Figure H-1).

Comments: Analyzing this large dataset of capture-recapture records collected at three banding stations over a 10-year period allowed for a robust assessment of annual variation in neotropical migrant abundance and species richness in Revelstoke Reach. Data shows clear annual differences in overall migrant abundance as well as annual differences in abundance of the most frequent species. While there were small differences in species richness among years, most common and abundant species were present every year. The difference in species richness among years was mostly driven by uncommon species whose low numbers did not affect overall abundance.

Table H-3: Annual variation in capture rate (captures/net hour) of newly captured individuals of different species of neotropical migrants at Machete Island banding station from 2008 to 2017. Species codes are defined in Table E-1.

Species	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	N total
COYE	0.137	0.241	0.137	0.180	0.201	0.287	0.102	0.222	0.170	0.387	4029
YRWA	0.050	0.162	0.026	0.024	0.074	0.096	0.043	0.078	0.084	0.559	2567
TRFL	0.056	0.063	0.057	0.046	0.070	0.096	0.108	0.070	0.110	0.104	1493
OCWA	0.032	0.057	0.023	0.073	0.021	0.097	0.022	0.050	0.021	0.204	1115
YWAR	0.026	0.074	0.026	0.049	0.019	0.088	0.037	0.036	0.024	0.190	1113
AMRE	0.027	0.045	0.031	0.073	0.037	0.041	0.103	0.073	0.052	0.125	1091
WIWA	0.028	0.016	0.042	0.021	0.008	0.020	0.043	0.030	0.019	0.084	643
SWTH	0.040	0.013	0.053	0.037	0.031	0.029	0.019	0.022	0.033	0.038	627
WAVI	0.027	0.033	0.034	0.030	0.012	0.063	0.039	0.010	0.032	0.043	619
REVI	0.018	0.022	0.024	0.030	0.027	0.047	0.038	0.017	0.039	0.048	561
GRCA	0.014	0.023	0.023	0.024	0.016	0.035	0.029	0.023	0.024	0.037	469
MGWA	0.014	0.025	0.013	0.009	0.004	0.029	0.026	0.015	0.018	0.072	461
LISP	0.019	0.016	0.022	0.037	0.008	0.026	0.017	0.025	0.018	0.029	406
SOSP	0.011	0.012	0.006	0.015	0.012	0.028	0.038	0.026	0.024	0.028	352
LEFL	0.013	0.010	0.011	0.006	0.006	0.013	0.034	0.025	0.016	0.024	309
CEDW	0.010	0.005	0.008	0.003	.	0.001	0.013	0.017	0.019	0.015	211
VEER	0.005	0.004	0.004	0.006	0.004	0.021	0.011	0.012	0.014	0.018	177
RCKI	0.007	0.002	0.010	0.003	0.002	0.006	0.008	0.011	0.011	0.006	142
SAVS	0.005	0.007	0.004	0.003	.	0.012	0.006	0.009	0.005	0.010	123
TEWA	0.002	0.006	0.002	0.012	0.002	0.003	0.006	<0.001	0.008	0.021	115
NOWA	0.007	0.003	0.004	0.009	0.004	0.002	0.010	0.005	0.004	0.012	110
PISI	0.011	0.001	0.002	.	0.025	.	0.012	0.003	0.010	.	101
WCSP	0.004	0.004	0.004	0.006	0.002	0.001	0.001	0.004	0.003	0.002	68
EAKI	.	0.002	0.001	.	0.004	0.001	0.003	0.008	0.008	0.002	61
WEWP	0.002	0.002	0.002	.	0.002	0.002	0.007	0.007	0.003	0.003	59
DEJU	0.001	0.003	0.004	0.006	0.002	0.001	0.002	0.003	0.003	0.002	55
LAZB	0.001	0.004	<0.001	0.006	.	0.004	.	0.002	0.004	0.006	54
AMGO	0.001	0.009	0.002	.	.	.	.	0.001	.	0.003	49
CCSP	0.001	0.003	0.001	.	.	0.003	0.002	0.004	0.004	0.003	49
AMRO	0.001	0.001	0.001	.	0.002	.	0.008	0.002	0.006	0.003	45
WETA	<0.001	0.004	0.001	0.003	.	.	0.003	0.003	0.002	0.004	40
NAWA	0.001	0.002	.	0.003	.	0.001	.	<0.001	0.001	0.010	37
TOWA	0.001	0.002	0.002	0.003	.	.	.	0.001	0.001	0.008	35
RWBL	.	0.003	0.001	.	.	.	.	0.006	0.002	.	32
HAFL	0.001	0.003	0.002	.	.	.	.	0.003	0.001	0.002	30
MAWA	0.001	0.001	0.001	0.006	.	0.002	0.001	0.001	0.001	0.004	28
CHSP	0.001	0.002	<0.001	.	.	0.006	0.001	0.002	<0.001	0.002	27
HETH	<0.001	0.002	0.003	.	.	.	0.001	0.001	0.001	0.001	26
DUFL	0.001	0.002	0.002	.	.	.	.	0.001	0.001	<0.001	23
GCKI	.	.	<0.001	.	0.002	.	.	0.001	0.002	0.002	15
CAVI	0.001	0.001	0.001	.	.	.	0.001	<0.001	0.001	.	13
SWSP	0.001	<0.001	.	0.003	0.002	0.006	.	.	.	.	11
BHGR	<0.001	.	0.001	.	.	.	.	0.001	<0.001	0.002	10
FOSP	<0.001	.	0.001	.	.	.	.	0.001	<0.001	0.001	10
MAWR	0.001	<0.001	.	.	.	0.001	.	.	.	0.002	9
BHCO	.	<0.001	.	.	.	.	.	0.001	<0.001	0.002	8
BLPW	.	<0.001	.	.	.	0.001	.	.	.	0.001	5
PSFL	.	0.001	.	.	.	0.001	.	.	<0.001	.	4
YBCH	.	.	.	.	.	.	.	.	<0.001	0.001	4
MOWA	.	<0.001	.	0.003	.	.	.	<0.001	.	.	3
OSFL	<0.001	.	.	.	.	.	.	<0.001	<0.001	.	3
CSWA	.	.	<0.001	.	.	.	.	.	<0.001	.	2
BAWW	.	.	<0.001	.	.	.	.	.	.	.	1
BRSP	.	.	.	.	.	.	.	.	<0.001	.	1
GCSP	.	.	.	.	.	.	.	.	<0.001	.	1
HOWR	.	<0.001	.	.	.	.	.	.	.	.	1
INBU	.	.	.	.	.	.	.	<0.001	.	.	1

Table H-4: Annual variation in capture rate of newly captured individuals of different species of neotropical migrants at Airport Islands from 2011 to 2017. Species codes are defined in Table E-1.

Species	2011	2012	2013	2014	2015	2016	2017	N total
COYE	0.311	0.054	0.157	0.141	0.127	0.105	0.172	368
YRWA	0.154	0.123	0.019	0.019	0.046	0.026	0.217	180
SAVS	0.086	0.037	0.084	0.064	0.067	0.014	0.041	148
LISP	0.045	0.010	0.008	0.045	0.014	0.009	0.045	55
TRFL	0.008	.	0.013	0.011	0.018	0.017	0.041	34
YWAR	0.015	0.003	0.005	0.013	0.025	0.017	0.005	27
OCWA	0.011	0.003	0.005	.	0.039	0.003	0.023	24
SOSP	0.011	0.003	0.008	0.021	.	0.003	.	18
CEDW	.	.	.	0.019	0.007	.	.	9
CCSP	0.004	0.005	.	0.003	0.011	.	.	7
WIWA	0.008	.	.	0.003	0.011	.	0.005	7
SWSP	0.004	0.005	0.003	.	.	.	.	5
AMRE	.	.	.	.	0.004	0.006	.	3
DEJU	.	.	.	.	.	0.006	0.005	3
LAZB	.	.	.	.	.	0.009	.	3
LEFL	.	.	..	0.005	0.004	.	.	3
MAWR	.	.	0.002	0.003	.	.	0.005	3
MGWA	0.008	.	.	.	.	.	0.005	3
NOWA	.	.	.	0.003	.	.	0.009	3
WCSP	0.008	.	.	0.003	.	.	.	3
RCKI	.	.	.	.	0.004	.	0.005	2
RWBL	0.008	.	.	.	.	.	.	2
WEME	.	.	.	.	0.007	.	.	2
YHBL	.	.	.	.	.	0.006	.	2
BHCO	.	0.003	.	.	.	.	.	1
GRCA	.	.	0.002	.	.	.	.	1
HAFL	.	.	0.002	.	.	.	.	1
SWTH	.	.	.	.	.	.	0.005	1
TOWA	.	.	.	.	.	0.003	.	1
WPWA	.	.	0.002	.	.	.	.	1

Table H-5: Annual variation in capture rate of newly captured individuals of different species of neotropical migrants at Jordan River from 2011 to 2017. Species codes are defined in Table E-1.

Species	2011	2012	2013	2014	2015	2016	2017	N total
WAVI	0.114	0.115	0.147	0.124	0.196	0.093	0.138	417
SWTH	0.187	0.131	0.126	0.101	0.132	0.117	0.127	410
YRWA	0.021	0.041	0.003	0.023	0.008	0.003	0.531	198
AMRE	0.030	0.047	0.045	0.063	0.060	0.107	0.138	196
MGWA	0.024	0.054	0.030	0.021	0.038	0.028	0.047	111
GCKI	0.027	0.018	0.012	0.042	0.057	0.083	0.040	103
TRFL	0.027	0.036	0.022	0.033	0.026	0.024	.	83
YWAR	0.018	0.031	0.019	0.033	0.019	0.010	0.033	76
RCKI	0.003	0.004	0.041	0.019	0.049	0.041	0.007	74
DEJU	0.021	0.019	0.041	0.008	0.030	0.028	.	73
SOSP	0.030	0.034	0.017	0.021	0.011	0.021	0.018	72
WIWA	0.018	0.015	0.014	0.027	0.053	0.014	0.022	65
REVI	0.012	0.020	0.027	0.015	0.019	0.010	0.018	61
CEDW	0.012	0.018	0.006	0.019	0.008	0.014	0.007	39
LISP	0.009	0.007	0.006	0.008	0.019	0.014	0.004	27
AMRO	0.003	0.013	0.009	0.012	0.004	0.003	0.004	26
GRCA	0.012	0.010	0.003	0.010	0.011	0.010	.	24
COYE	0.009	0.006	0.001	0.015	.	0.010	0.011	22
OCWA	.	0.006	0.006	.	0.011	0.007	0.022	20
TOWA	0.018	0.010	0.001	.	.	.	0.004	15
HAFL	0.003	0.007	0.001	0.002	0.004	0.003	0.015	14
HETH	.	0.002	0.008	0.002	0.004	0.010	0.004	13
LEFL	.	0.006	0.004	0.002	0.004	0.010	.	12
PISI	.	0.002	.	0.019	.	.	.	11
VEER	0.003	0.003	0.003	.	0.011	.	0.007	10
LAZB	0.003	0.003	0.001	0.002	0.004	0.007	0.004	9
NAWA	0.003	0.009	0.001	.	0.004	.	.	9
TEWA	0.006	0.006	.	0.002	.	.	0.007	9
MAWA	0.003	.	0.004	0.004	0.004	.	0.004	8
CAVI	0.003	0.002	0.003	.	0.004	0.003	0.004	7
WCSP	0.006	.	0.001	.	0.015	.	.	7
NOWA	.	0.004	0.001	0.004	.	.	.	6
SAVS	0.006	0.003	.	0.002	.	.	.	5
WETA	0.003	.	0.001	.	0.004	0.003	0.004	5
FOSP	.	0.002	0.001	.	.	.	0.004	3
CHSP	.	.	0.001	0.002	.	.	.	2
PSFL	.	0.003	.	.	.	.	.	2
CCSP	.	0.002	.	.	.	.	.	1
CSWA	.	.	.	.	0.004	.	.	1

Table H-6: Inter-annual difference in the number of newly captured birds (corrected for survey effort) at Machete Island (Chi-square goodness-of-fit test; *** = p < 0.001).

Species	χ^2	df	p
COYE	594.6	9	***
YRWA	3549.7	9	***
TRFL	126.6	9	***
AMRE	324	9	***
YWAR	878.5	9	***
OCWA	1007.3	9	***
SWTH	104.5	9	***
WAVI	81.1	9	***
WIWA	240.5	9	***
REVI	82.1	9	***

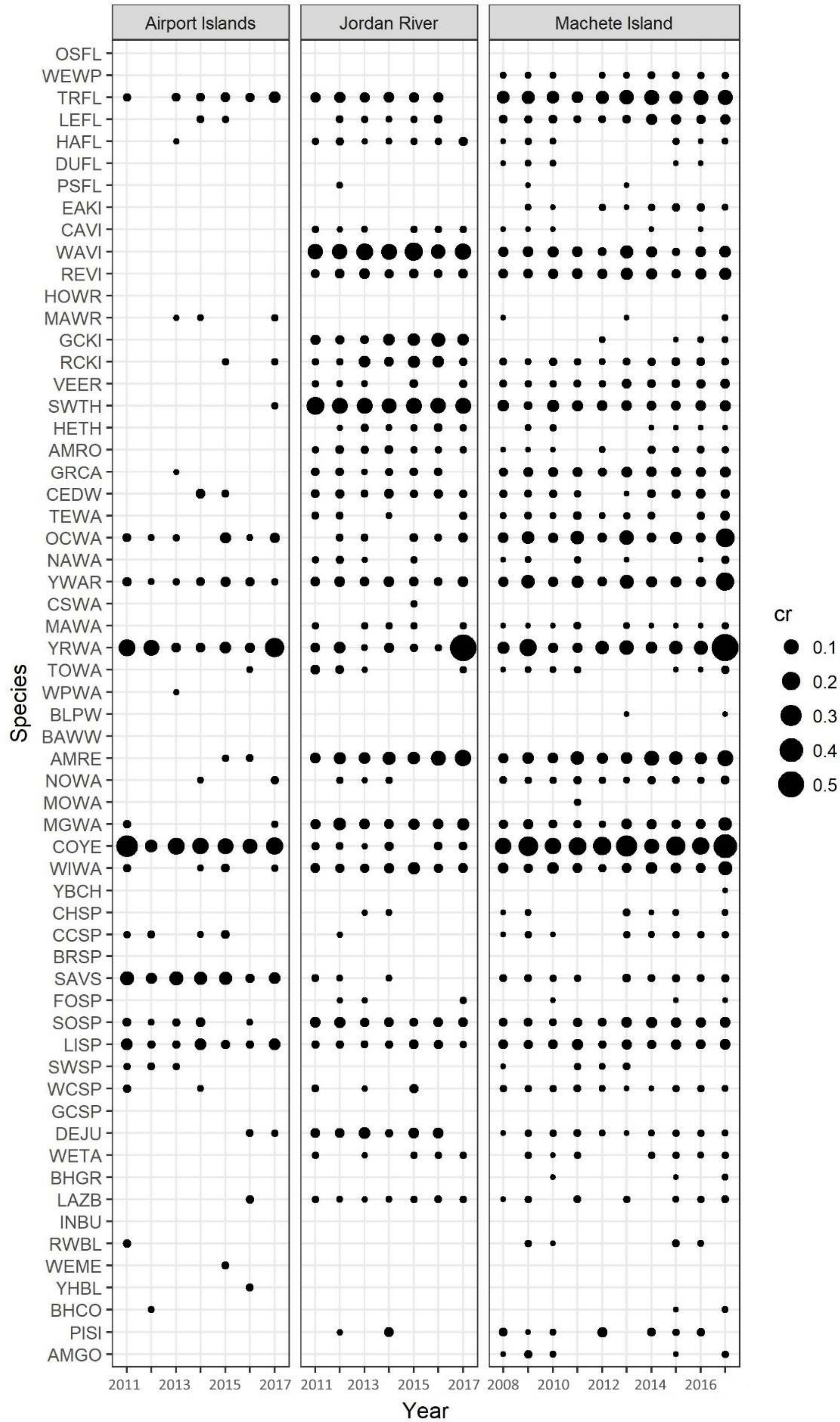


Figure H-1: Annual variation in capture rate of different species at Machete Island banding station, Airport Islands banding station and Jordan River banding station from 2008 to 2017. Cr = capture rate (birds/net-hour). Species codes are defined in Table E-1.

Appendix I. Annual variation in neotropical migrant presence in Revelstoke Reach in 2008 to 2017.

Introduction: This summary was compiled to describe annual variation in neotropical migrant presence in Revelstoke Reach during fall migration.

Dataset: Dataset #1 was used, but only data collected in fall (CLBMON-39) were included in the summary. This dataset consisted of 10 years of data from all components of the CLBMON-39 study (all banding stations, permanent, random, and effectiveness monitoring plot surveys) as well as all observations of migrants recorded during banding operations (presence/absence data only).

Analyses: This is a summary of presence/absence data. Data was visualized using the ggplot2 package for R (Wickham 2016).

Results: Of the 73 species of neotropical migrants, 36 species were documented in all years of monitoring (Figure I-1). Most common and abundant migrant species were detected every year of monitoring. This included all the species that each accounted for more than 2.5% of all captured individuals.

Comments: While banding station data provided invaluable quantitative data on migrant annual abundance and species richness and their variation among years, not all species of migrants could be reliably captured in the mist nets (e.g., swallows).

Species that were not recorded every year generally fell into one of four categories: (1) species which were detected outside of their usual geographical range and which do not normally frequent Revelstoke Reach (e.g., Prairie Warbler, Palm Warbler, Black-and-white Warbler, Indigo Bunting), (2) species which are probably present annually but which are detected rarely during fall migration in the drawdown zone because they occupy habitat not sampled intensively every year (e.g., Olive-sided Flycatcher, Golden-crowned Sparrow, Townsend's Solitaire, swallows, Marsh Wren), (3) species which are regular but uncommon and/or secretive species which can be easily missed during fall migration (e.g., Black-headed Grosbeak, Bullock's Oriole), and (4) species which are very rare and are present in some years but not others (e.g., Swamp Sparrow, Yellow-breasted Chat).

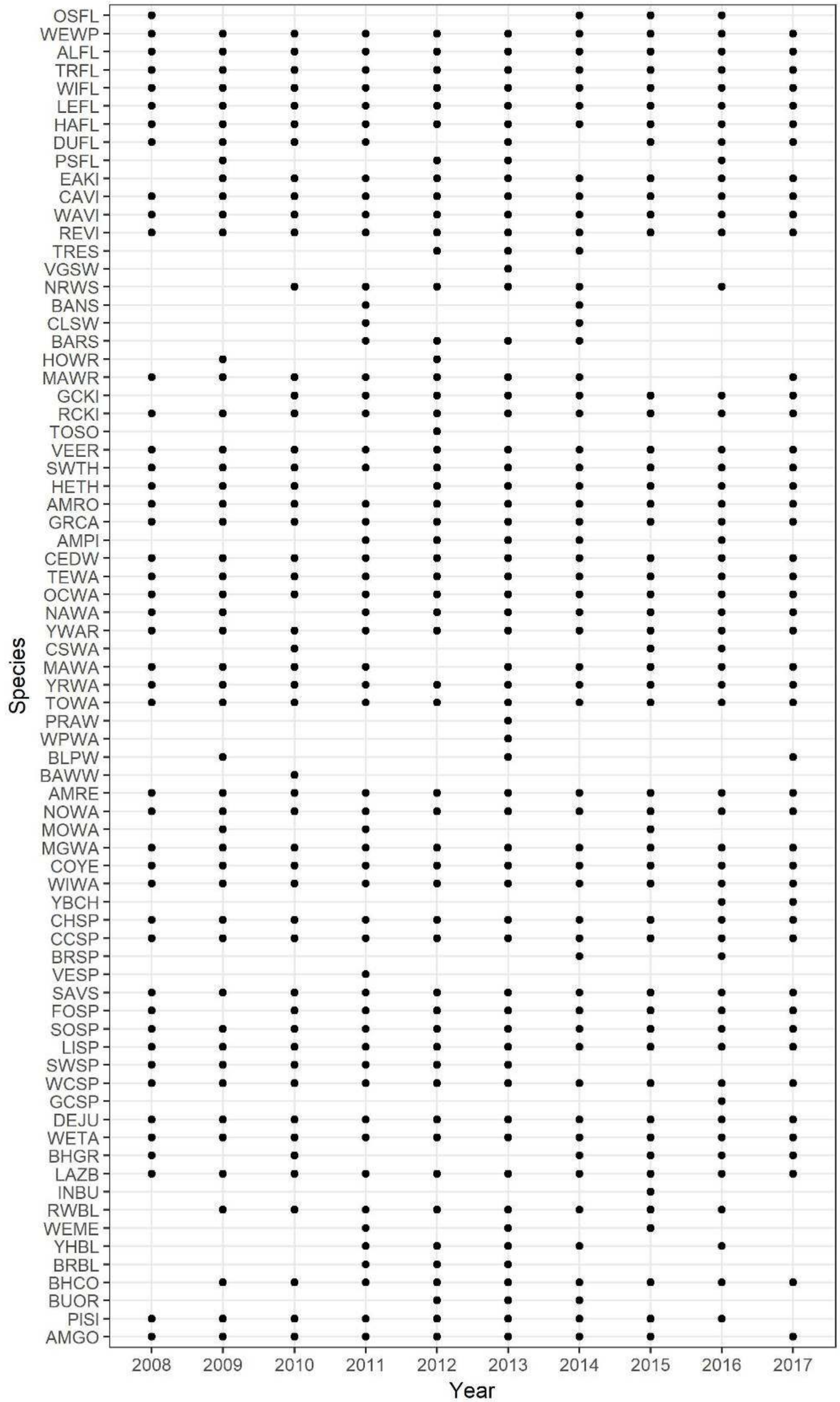


Figure I-1: Detections of neotropical migrant species in Revelstoke Reach in different years of CLBMON-39 monitoring. Pooled data from banding, plot surveys, and incidental observations. Species codes are defined in Table E-1.

.

Appendix J. Assessing seasonal variation in neotropical migrant abundance and species richness in Revelstoke Reach during spring migration.

Introduction: This summary was compiled to describe seasonal variation in abundance and species richness of neotropical migrants in Revelstoke Reach during spring migration.

Dataset: Dataset #5 was used. This dataset consists of CLBMON-11B2 data from random plot surveys, permanent plot surveys, and effectiveness monitoring plot surveys (on plot, off plot, and overhead observations), and contains data from all seven years of monitoring (2009-2014 and in 2016). In total, 10,269 bird records of 65 species of neotropical migrant songbirds were detected in spring.

Analysis: Data were plotted using the ggplot2 package for R (Wickham 2016).

Results: The most frequently recorded species during spring migration was American Pipit (23.6% of all bird observations), followed by Yellow-rumped Warbler (15.3%), American Robin (7.6%), Tree Swallow (7.8%), Savannah Sparrow (4.0%), Ruby-crowned Kinglet (3.9%), Violet-green Swallow (3.8%), Yellow Warbler (3.3%), Northern Rough-winged Swallow (3.1%), Pine Siskin (2.7%), Chipping Sparrow (2.7%), and White-crowned Sparrow (2.6%).

The timing and intensity of spring migration of all recorded species can be seen in Figure J-1.

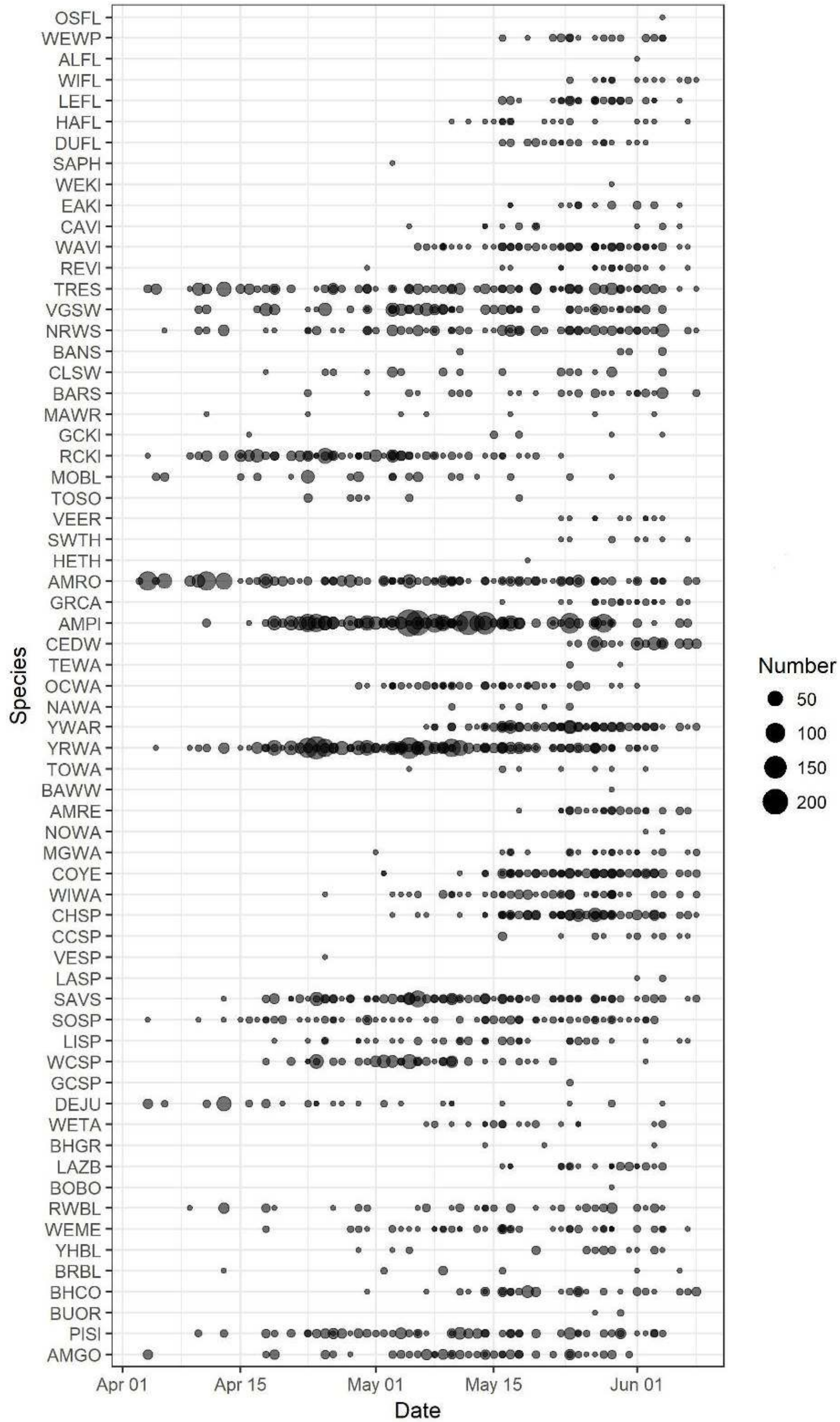


Figure J-1: Seasonal distribution of neotropical migrants recorded during spring migration in Revelstoke Reach in 2009 to 2016. Pooled data from random plot, permanent plot, and effectiveness monitoring plot surveys.

Appendix K. Assessing neotropical migrant abundance and species richness in different habitat strata during fall migration.

Introduction: This analysis was conducted to assess variation in fall neotropical migrant abundance and species richness among broad habitat strata in Revelstoke Reach.

Methods: As a first step, random plots were assigned to habitat strata based on vegetation collected on plots after each survey. Random plots were assigned into four habitat strata using the following criteria:

Forest stratum = tree cover ≥ 5%

Shrub stratum = tree cover < 5% and shrub cover ≥ 5%

Grassland stratum = tree cover < 5% and shrub cover < 5% and herbaceous cover ≥ 5%

Unvegetated stratum = tree cover < 5% and shrub cover < 5% and herbaceous cover < 5%

In total, 60 plots were assigned to forest strata, 63 to shrub strata, 73 to grassland strata and 24 to unvegetated strata.

Dataset: For this analysis, dataset #6 was used, which contained data from four years of surveys of random plots. In total, 220 random plots were included (44 plots in 2011, 61 in 2012, 98 in 2013, and 17 in 2014). Mean abundance is reported (± SD), in units of birds per plot per survey (30 minutes); plots were 50 m x 50 m.

Analysis: Due to non-normality of the data (both for abundance and species richness), a Kruskal-Wallis test was used to investigate differences in abundance and species richness among broad habitat strata. Post-hoc Mann-Whitney tests with a Bonferroni correction were used to reveal differences within groups.

Results: The abundance and species richness of fall neotropical migrants varied among strata (Table K-1, Figure 5). The abundance of migrants on plot was significantly different among strata (Kruskal-Wallis: $\chi^2(3) = 30.2$, $p < 0.001$). Forest plots had significantly higher abundance than grassland plots ($p < 0.001$, $r = 0.33$) and unvegetated plots ($p < 0.001$, $r = 0.46$). Similarly, shrub plots had significantly higher abundance than grassland ($p < 0.01$, $r = 0.24$) and unvegetated plots ($p < 0.001$, $r = 0.43$). In addition, grassland plots had higher abundance than unvegetated plots ($p < 0.05$, $r = 0.26$). Forest plots had higher abundance of migrants than shrub plots, but the difference was not statistically significant ($p = 0.14$, $r = 0.13$).

Table K-1: Abundance and species richness of fall neotropical migrant songbirds on random plot by broad habitat strata.

Habitat strata	No. of Plots	Abundance		Species richness	
		Mean	SD	Mean	SD
Forest	60	3.60	5.403	1.42	1.565
Grassland	73	0.67	1.167	0.44	0.645
Shrub	63	1.86	3.277	1.06	1.401
Unvegetated	24	0.13	0.448	0.08	0.282

Similar to abundance, the species richness of fall migrants was also significantly different among strata (Table K-1; Kruskal-Wallis: $\chi^2(3) = 30.3$, $p < 0.001$). Forest plots had significantly higher species richness than grassland plots ($p < 0.001$, $r = 0.33$) and unvegetated plots ($p < 0.001$, $r = 0.46$), and shrub plots had significantly higher species richness than grassland ($p < 0.01$, $r = 0.25$) and unvegetated plots ($p < 0.001$, $r = 0.44$). Grassland plots had higher species richness than unvegetated plots ($p < 0.05$, $r = 0.26$). Forest plots had higher species richness than shrub plots, but the difference was not significant ($p = 0.13$, $r = 0.11$).

Comments: This analysis described the habitat use by fall migrants with reasonable accuracy and in accordance with expectations. Despite large within-group variation, the differences between groups were significant. All strata were sampled with enough replications to avoid bias due to inherent variability in annual, seasonal, and time-of-day variation in bird presence and activity.

Appendix L. Assessing abundance and species richness of fall neotropical migrants in different habitat types.

Introduction: This analysis was conducted to assess variation in fall neotropical migrant abundance and species richness among habitat types in Revelstoke Reach.

Methods: Plots were assigned to habitat type (Appendix D) based on CBA habitat mapping (CBA 2016b). Each plot was assigned to the dominant habitat type on plot (excluding open water).

Dataset: This analysis used dataset #6, which contained data from four years of surveys of fall random plots. In total, 220 random plots were used (44 plots in 2011, 61 in 2012, 98 in 2013, and 17 in 2014). Mean abundance is reported (± SD), in units of birds per plot per survey (30 minutes); plots were 50 m x 50 m.

Analysis: The density of migrants for each habitat type was calculated based on the average abundance of migrants on plots assigned to that habitat type (pooled data from all years). Heat maps were produced by intersecting the habitat type map with a 50x50 m grid, then dissolving the polygons. The value of each of these 50x50 m cells is an average of the underlying density values from the habitat type within the cell.

Results: The abundance and diversity of fall migrants varied among habitat types (Table L-1). Of the 25 habitat types surveyed during CLBMON-39 monitoring (220 random plots), riparian forest habitat had the highest average abundance of migrants per survey (7.6 ± 7.09 (mean ± SD) birds/survey; n = 11), followed by swamp habitat (5.3 ± 5.77 birds/survey; n = 3), riparian shrub habitat (4.0 ± 5.97 birds/survey; n = 13), wet meadow habitat (3.5 ± 0.71 birds/survey; n = 2), and cattail habitat (3.0 ± 2.83 birds/survey; n = 2). Species richness was highest at plots in wet meadow habitat (3.0 ± 1.41 species/survey; n = 2), followed by swamp habitat (2.7 ± 2.89 species/survey, n = 2), riparian forest habitat (2.6 ± 1.12 species/survey; n = 11), and riparian shrub habitat (2.1 ± 1.71 species/survey; n = 13) (Table L-1). A map of modelled overall neotropical migrant density and species richness in Revelstoke Reach during fall migration is provided in Figure 6 and Figure L-1, respectively.

Discussion: The sample size allowed for estimation of migrant abundance and species richness reasonably well for dominant habitat types in the drawdown zone (e.g., mixed grassland, sparse grassland, sedge-grassland, shrub-savannah, riparian forest). For these, stratified random sampling allowed for a reasonably wide annual, seasonal, and time-of-day sampling variability. Estimates for all sampled habitat types were included, but sample size for some of them was very small. As such, care must be taken in interpreting these results. Moreover, it is important to note that the vegetation communities were assigned based on the dominant habitat type on plot and in some cases the bird observation could be biased by the presence of a patch of very attractive or unsuitable habitat on a plot, especially if sample size is small. However, the habitat types with small samples are, for the most part, the ones that are very localized and cover only a very small (less than 1%) area in the drawdown zone. All the estimates are presented, but caution should be taken when generalizing results of habitat types with small sample sizes.

Table L-1: Abundance and species richness of fall neotropical migrants on random plots by habitat type.

Habitat Type		Number of Plots	Abundance		Species Richness	
			Mean	SD	Mean	SD
Forest	Riparian forest	11	7.55	7.09	2.64	1.12
	Upland mixed forest	15	1.47	2.36	0.87	1.19
Grassland	Horsetail grassland	6	0.83	1.17	0.67	0.82
	Mixed grassland	23	0.57	1.34	0.26	0.45
	Sparse grassland	12	0.33	0.89	0.17	0.39
	Reed canary grass	2	1.00	0.00	1.00	0.00
	Sedge grassland	4	1.25	1.89	0.75	0.96
Shrub	Shrub savannah	54	2.39	4.21	1.06	1.45
	Riparian shrub	13	4.00	5.97	2.08	1.71
Unvegetated	Rocky bank	2	.	.	.	.
	Thalweg	10	0.90	1.52	0.50	0.85
	Gravel	11	0.09	0.30	0.09	0.30
	Sand	6	0.17	0.41	0.17	0.41
	Silt	1	.	.	.	.
	Urban	1	.	.	.	.
Wetland	Floating bog	2	1.00	0.00	1.00	0.00
	Bulrush	6	0.83	0.98	0.50	0.55
	Submerged buoyant bog	4	.	.	.	.
	Creek	1	.	.	.	.
	Cattail	2	3.00	2.83	1.50	0.71
	Low elevation draw	4	0.25	0.50	0.25	0.50
	Pond	16	0.44	0.89	0.38	0.81
	Swamp	3	5.33	5.77	2.67	2.89
	Wet meadow	2	3.50	0.71	3.00	1.41
	Water sedge	9	1.67	1.73	0.78	0.67

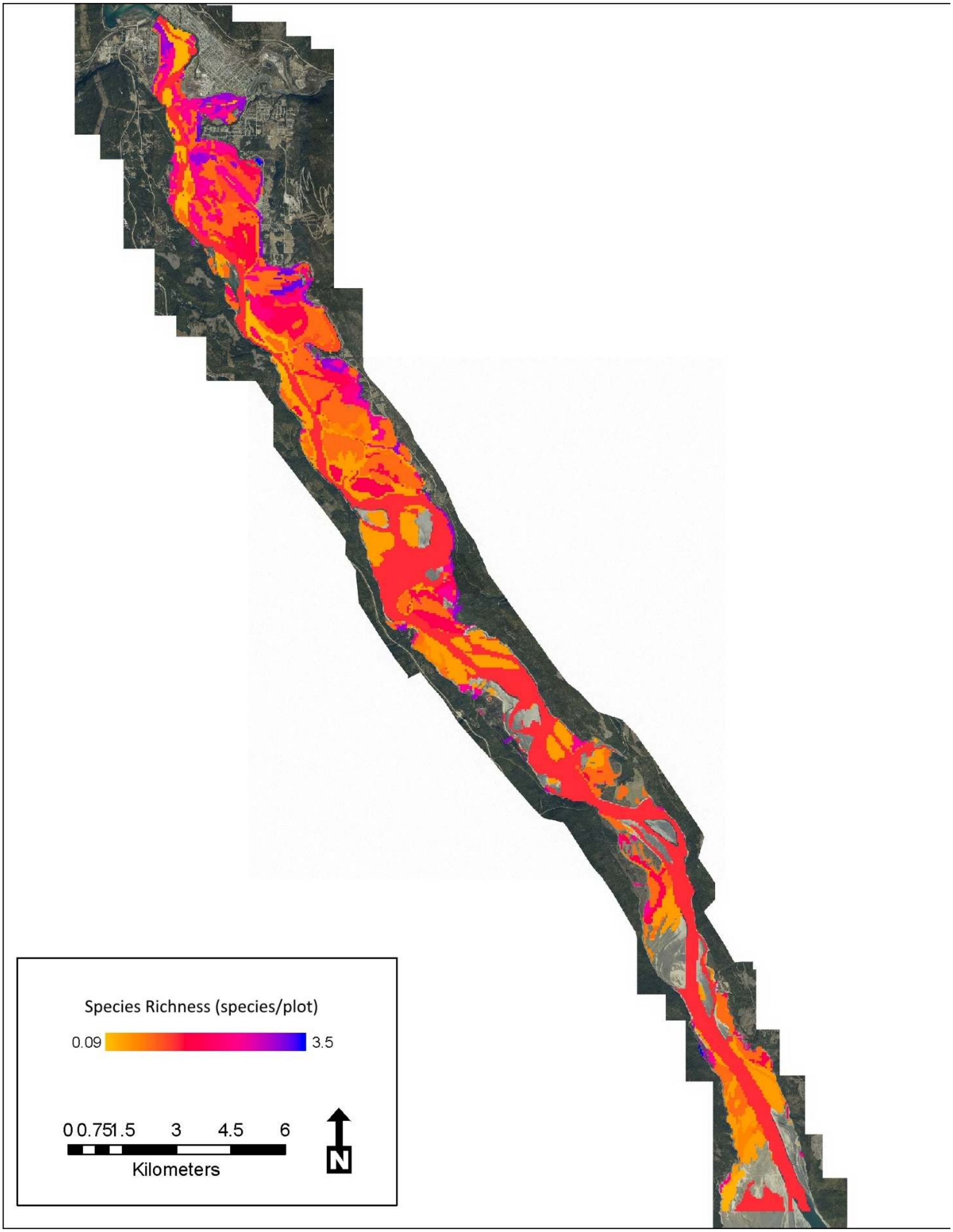


Figure L-1: Map of modelled neotropical migrant songbird species richness in Revelstoke Reach during fall migration (pooled data from all species are plotted).

Appendix M. Assessing variation in abundance of three families of migrants by strata and vegetation type during fall migration.

Introduction: This analysis was conducted to assess the variation in abundance of three main families of migrants in Revelstoke Reach during fall migration by broad strata and habitat type.

Dataset: This analysis was completed using dataset #5, which contained data from four years of random plot surveys. In total, 220 random plots were used (44 plots in 2011, 61 in 2012, 98 in 2013, and 17 in 2014).

For this analysis, three main families of migrants in Revelstoke Reach were analyzed separately: flycatchers (Tyrannidae), wood-warblers (Parulidae), and sparrows (Passerellidae). In addition, the habitat preferences of Common Yellowthroat were looked at separately because: (1) it is the most abundant fall migrant in the drawdown zone, and (2) its habitat preferences differ from most other wood-warblers (Common Yellowthroat often forages in herbaceous vegetation, often without any shrub presence, while most other wood-warblers prefer to forage in shrub or forest habitat). Mean abundance is reported (± SD), in units of birds per plot per survey (30 minutes); plots were 50 m x 50 m.

Analysis: The density of each migrant family for each habitat type was calculated based on the average abundance of these migrants on plots assigned to that habitat type (pooled data from all years). Heat maps were produced by intersecting the habitat type map with a 50x50 m grid, then dissolving the polygons. The value of each of these 50x50 m cells is an average of the underlying density values from the habitat type within the cell.

Results: The average abundance of flycatchers, wood-warblers, sparrows, and Common Yellowthroat during fall migration varied among habitat strata (Table M-1). Flycatchers and wood-warblers had the highest average abundance on plots in forest habitat (0.08 ± 0.381 birds/survey and 1.25 ± 2.832 birds/survey, respectively, n = 60). Common Yellowthroat and sparrows had the highest average abundance on plots from shrub habitat strata (0.43 ± 0.856 birds/survey and 0.59 ± 1.997 birds/survey, respectively, n = 63).

Table M-1: Abundance of flycatchers, wood-warblers, Common Yellowthroat (COYE), and sparrows on random plots during fall migration by broad habitat strata.

Habitat Strata	No. of Plots	Flycatchers		Warblers		COYE		Sparrows	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Grassland	73	.	.	0.26	0.646	0.26	0.646	0.32	0.814
Shrub	63	0.06	0.304	0.75	1.031	0.43	0.856	0.59	1.997
Forest	60	0.08	0.381	1.25	2.832	0.23	0.745	0.35	1.102
Unvegetated	24	.	.	0.08	0.408	.	.	.	.

The average abundance of flycatchers, wood-warblers, sparrows, and Common Yellowthroat varied among habitat types (Table M-2). The abundance of flycatchers was highest in swamp habitat (0.7 ± 1.15 bird/survey; n = 2), the abundance of wood-warblers was highest in riparian forest (2.4 ± 3.35 birds/survey; n = 11), and the abundance of sparrows was highest in wet meadow habitat (1.0 ± 0 birds/survey; n = 2). Common Yellowthroat, one of the most abundant migrants in Revelstoke Reach, had the highest abundance in cattail habitat (2.0 ± 1.41 birds/survey; n = 2). A map of the density of each of the three groups of migrants (flycatchers, wood-warbler, and sparrows) and Common Yellowthroat during fall migration in Revelstoke Reach is provided in Figure M-1.

Table M-2: Abundance of flycatchers, wood-warblers, Common Yellowthroat (COYE), and sparrows on random plots by habitat type.

Habitat Type		No. of	Flycatchers		Warblers		COYE		Sparrows	
		Plots	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Forest	Riparian forest	11	0.09	0.30	2.36	3.35	.	.	0.09	0.30
	Upland forest	15	0.13	0.52	0.27	0.59	0.07	0.26	0.07	0.26
Grassland	Horsetail grassland	6	.	.	0.17	0.41	0.17	0.41	0.67	0.82
	Mixed grassland	23	.	.	0.17	0.49	0.17	0.49	0.13	0.46
	Sparse grassland	12	.	.	0.25	0.87	.	.	0.08	0.29
	Reed canary grass	2	.	.	.	.	.	.	0.50	0.71
	Sedge grassland	4	.	.	0.50	0.58	0.50	0.58	0.75	1.5
Shrub	Shrub savannah	54	0.06	0.30	0.98	2.45	0.41	0.90	0.72	2.27
	Riparian shrub	13	.	.	1.31	1.97	0.23	0.83	0.85	1.52
Unvegetated	Rocky bank	2	.	.	.	.	.	.	.	.
	Thalweg	10	.	.	0.50	0.85	0.10	0.32	0.20	0.63
	Gravel	11	.	.	.	.	.	.	.	.
	Sand	6	.	.	.	.	.	.	0.17	0.41
	Silt	1	.	.	.	.	.	.	.	.
	Urban	1	.	.	.	.	.	.	.	.
Wetland	Floating bog	2	.	.	0.50	0.71	0.50	0.71	0.50	0.71
	Bulrush	6	.	.	0.50	0.84	0.50	0.84	.	.
	Submerged buoyant bog	4	.	.	.	.	.	.	.	.
	Creek	1	.	.	.	.	.	.	.	.
	Cattail	2	.	.	2.00	1.41	2.00	1.41	.	.
	Low elevation draw	4	.	.	.	.	.	.	0.25	0.50
	Pond	16	0.06	0.25	0.13	0.5	0.13	0.50	0.19	0.54
	Swamp	3	0.67	1.15	2.00	0	1.67	0.58	0.33	0.58
	Wet meadow	2	.	.	2.00	0	1.50	0.71	1.00	0
	Water sedge	9	.	.	0.89	1.36	0.89	1.36	0.67	1.66

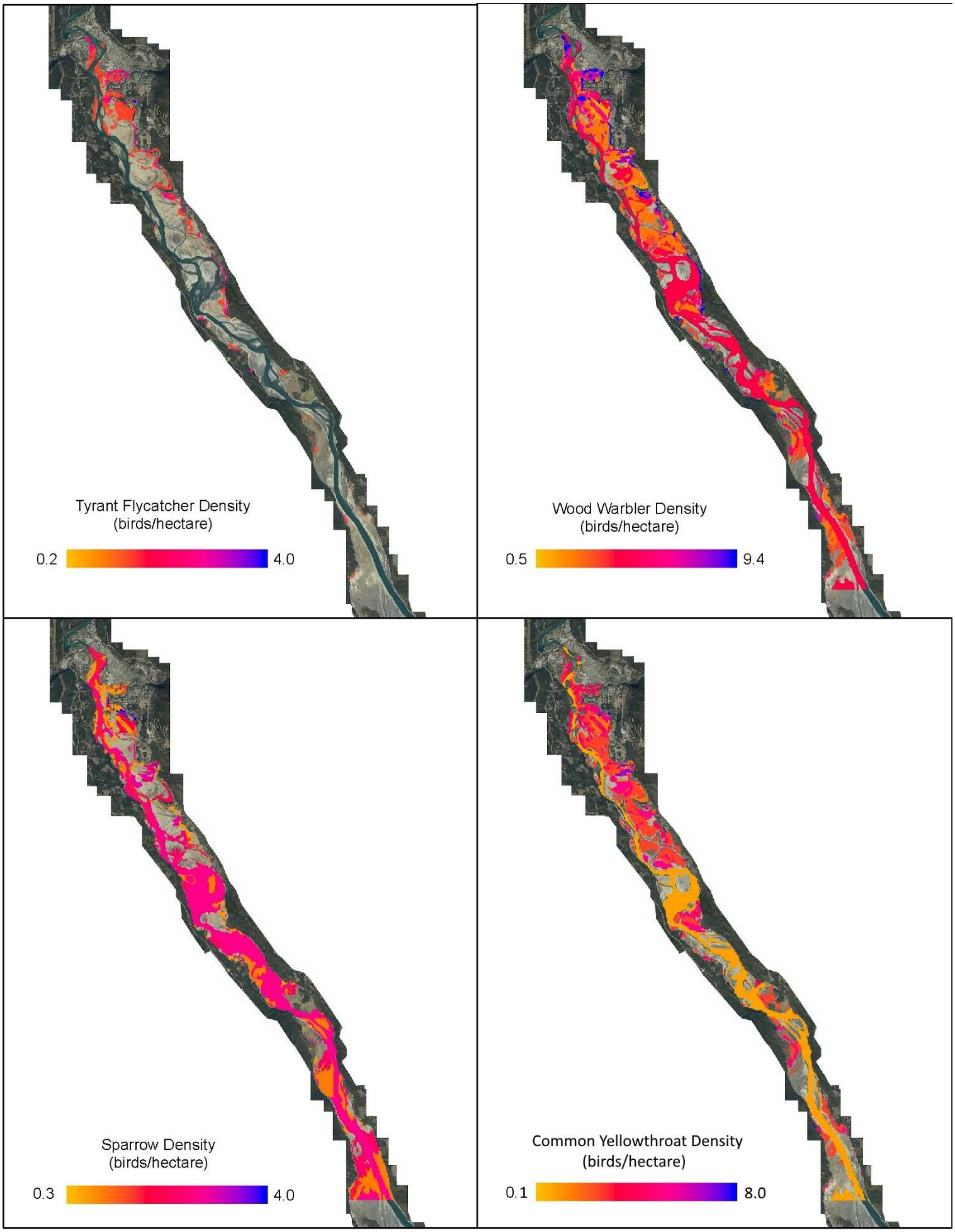


Figure M-1: Map of modelled density of tyrant flycatchers, wood-warbler, sparrow, and Common Yellowthroat in Revelstoke Reach during fall migration.

Comments: While pooling all species together allowed us to estimate overall abundance and species richness in different habitats, not all species had the same habitat preferences. Robust sample sizes for each broad habitat strata allowed for reasonably accurate estimates of abundance and species richness. For habitat types, estimates should be interpreted with caution because: (1) the small sample size of some habitat types, (2) habitat type was assigned based on dominant vegetation community on plot. As such, bird abundance and species diversity can be biased by the presence of a small area of high quality or inappropriate habitat on those plots.

Appendix N. Assessing variation in abundance and species richness of fall migrants based on vegetation cover.

Introduction: This analysis was conducted to assess variation of fall neotropical migrant abundance and species richness in Revelstoke Reach based on vegetation cover.

Methods: Habitat data collected on random plots after each survey was used to assign forest, shrub, and herbaceous vegetation cover to each random plot.

Dataset: Dataset #5 was used for this analysis, but only data from plots assigned to forest, shrub and grassland strata were included (unvegetated plots were excluded). This dataset (n=196) contained data from four years of surveys of random plots (38 plots in 2011, 57 in 2012, 85 in 2013 and 16 in 2014).

Analysis: This analysis examined the effects of vegetation cover (forest, shrub, and herbaceous cover) on abundance and species richness of neotropical migrants on random plots. Due to an excess of zeroes (plots with no birds detected) in the dataset, hurdle model structure from the 'pscl' package for R (Zeileis et al. 2008, Jackman 2017) was used to model migrant abundance on plot. In these models, binomial distribution was used to model the hurdle component for the zero counts and a negative binomial distribution was used to model the truncated count component. The model with a negative binomial distribution in the count component fit data better and received more support than the model with a Poisson distribution. Species richness on plot was modeled using generalized linear models (GLM) with a negative binomial distribution, which fit data better than a Poisson distribution. Package MASS for R was used to run the GLM models (Venables and Ripley 2002).

First, univariate models were used to confirm the relationship between abundance and species richness of migrants on plot and three temporal variables that were previously found to influence neotropical abundance in the Revelstoke Reach: (1) time of day when the survey was initiated, (2) day of the year when the survey was conducted (Julian date), and (3) year to account for annual differences in migrant abundance and reservoir operations. In the final models, controlling for significant temporal variables, the abundance of migrants (or species richness) on plot was modelled as a function of tree/shrub/herbaceous cover on plot. Estimates from all the models are presented on logit scale (presence) or log scale (count and species richness) and likelihood-based confidence intervals were calculated using the MASS package (Venables and Ripley 2002). R package visreg (Breheny and Burchett 2017) was used to transform and visualize fitted relationships on the original scale.

Results: The abundance of migrants on plots was negatively affected by time since sunrise (presence: estimate (Log odds)(95% CI) = -4.876 (-9.378, -0.375); and count: estimate (Log) = -5.742 (-11.748, 0.265)) and varied among years but was independent of Julian date.

Controlling for time after sunrise and year, tree cover had a marginally significant positive effect on the presence of migrants on plot (estimate (Log odds) = 0.012 (-0.002, 0.025) (Figure N-1) and significant positive effect on the number of migrants on plot (estimate (Log) = 0.020 (0.006, 0.035) (Figure N-4).

Controlling for time after sunrise and year, shrub cover had a significant positive effect on both the presence of migrants on plot (estimate (Log odds) = 0.049 (0.027, 0.071) (Figure N-2) and the number of migrants on plot (estimate (Log) = 0.023 (0.006, 0.040) (Figure N-5).

Controlling for time after sunrise and year, herbaceous cover (percent of plot covered by herbaceous vegetation) did not have an effect on the presence of migrants on plot (estimate (Log odds) = -0.003 (-0.013, 0.006) (Figure N-3) and had a marginally negative effect on the number of migrants on plot (estimate (Log) = -0.013 (-0.025, -0.000) (Figure N-6).

The species richness of migrants on plots varied among years and was only weakly negatively affected by time since sunrise (estimate (Log) (95% CI) = -2.702 (-5.851, 0.392) and it was independent of Julian date.

Controlling for time after sunrise and year, the species richness of neotropical migrants was positively affected by tree cover (estimate (Log) (95% CI) = 0.014 (0.006, 0.021); Figure N-7) and shrub cover (estimate (Log) = 0.027 (0.019, 0.035); Figure N-8). Conversely, herbaceous cover had a negative effect on species richness (estimate (Log) = -0.006 (-0.013, -0.000); Figure N-9).

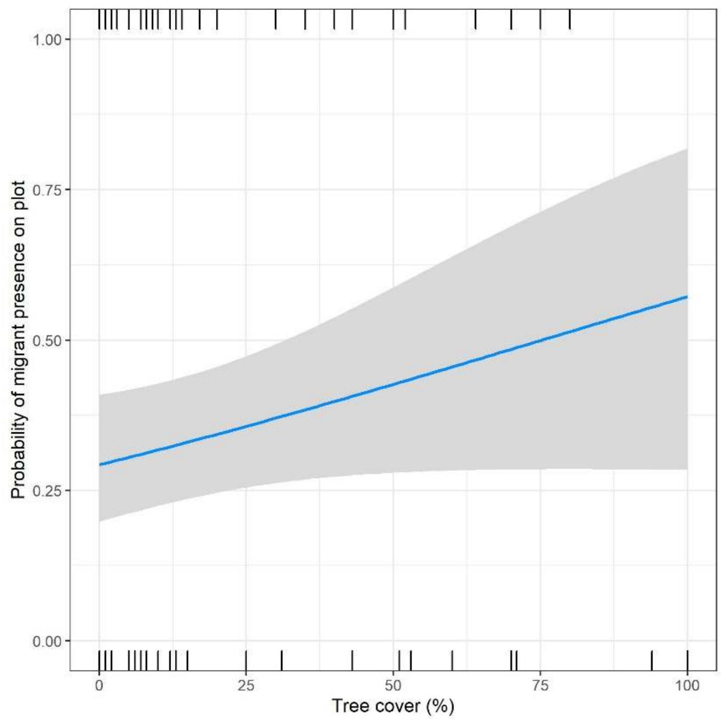


Figure N-1: Relationship between the area of plot covered by trees and probability of neotropical migrant presence on random plots. The blue line is the model prediction, the gray area is the 95% confidence interval.

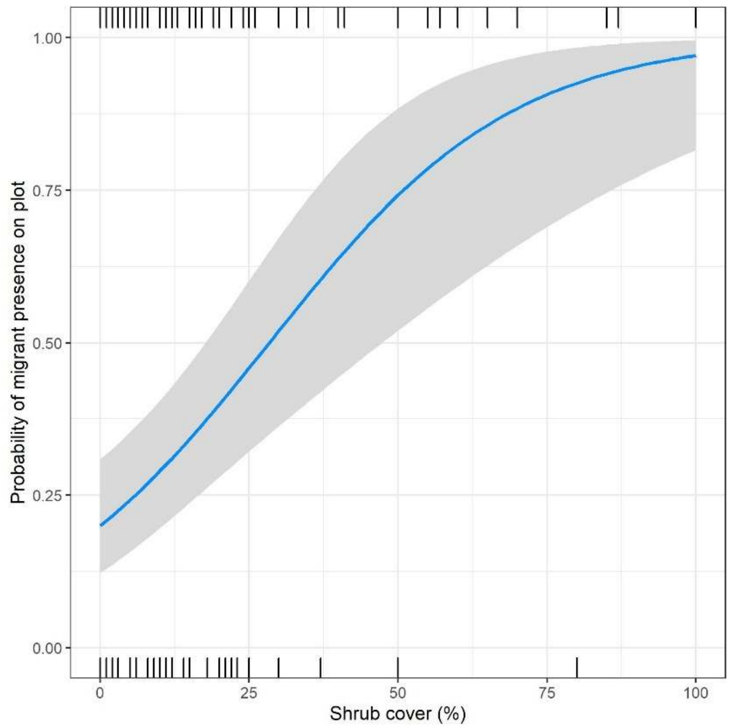


Figure N-2: Relationship between the area of plot covered by shrubs and probability of neotropical migrant presence on random plots. The blue line is the model prediction, the gray area is the 95% confidence interval.

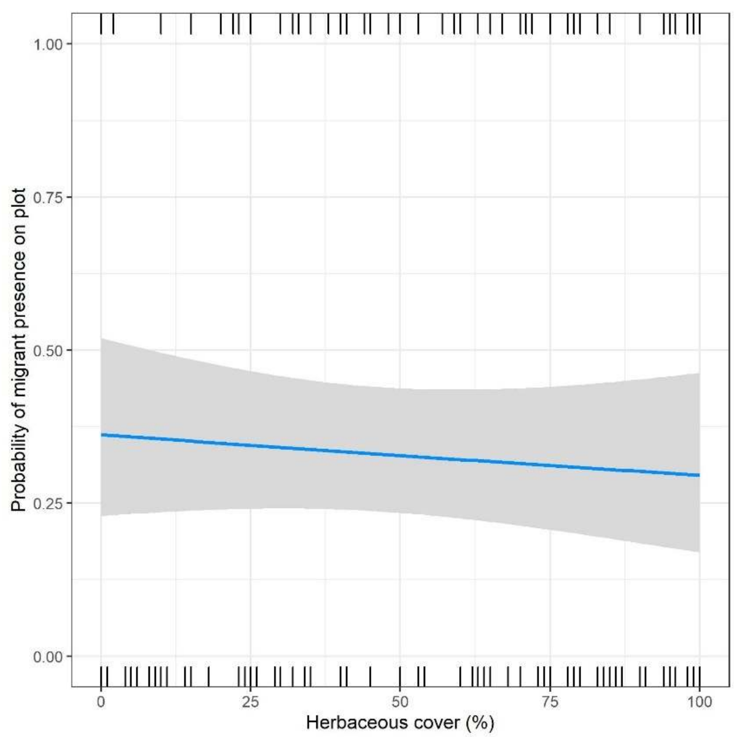


Figure N-3: Relationship between the area of plot covered by herbaceous vegetation and the probability of neotropical migrant presence on random plots. The blue line is the model prediction, the gray area is the 95% confidence interval.

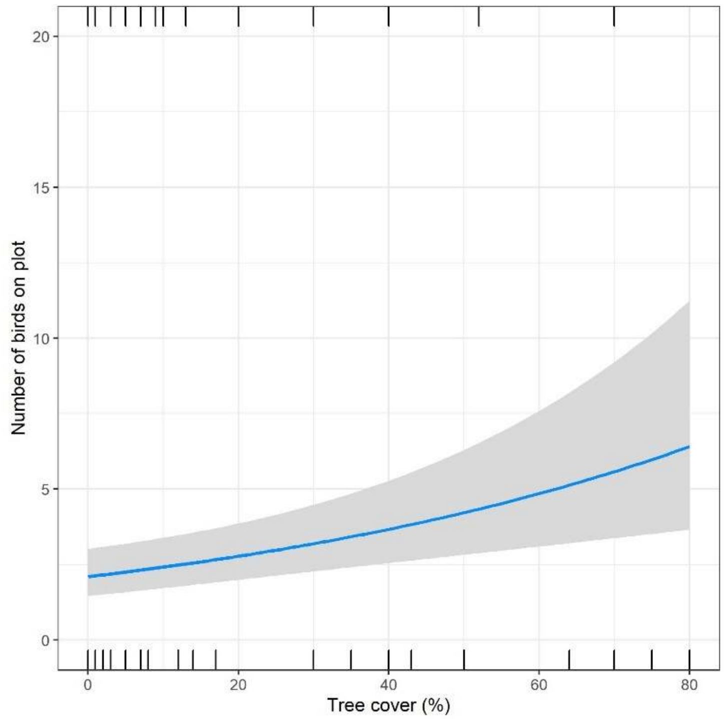


Figure N-4: Relationship between the area of plot covered by trees and number of detected neotropical migrants on random plots. The blue line is the model prediction, the gray area is the 95% confidence interval.

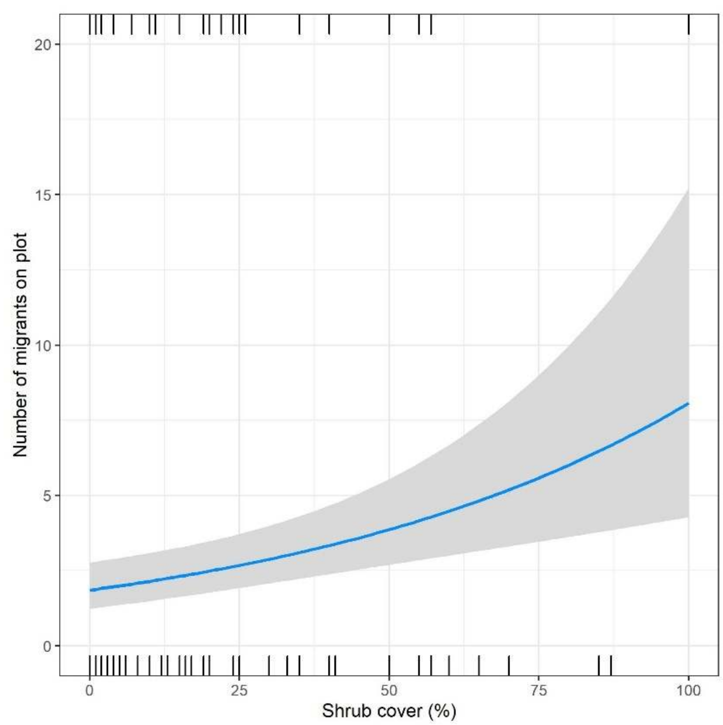


Figure N-5: Relationship between the area of plot covered by shrubs and number of detected neotropical migrants on random plots. The blue line is the model prediction, the gray area is the 95% confidence interval.

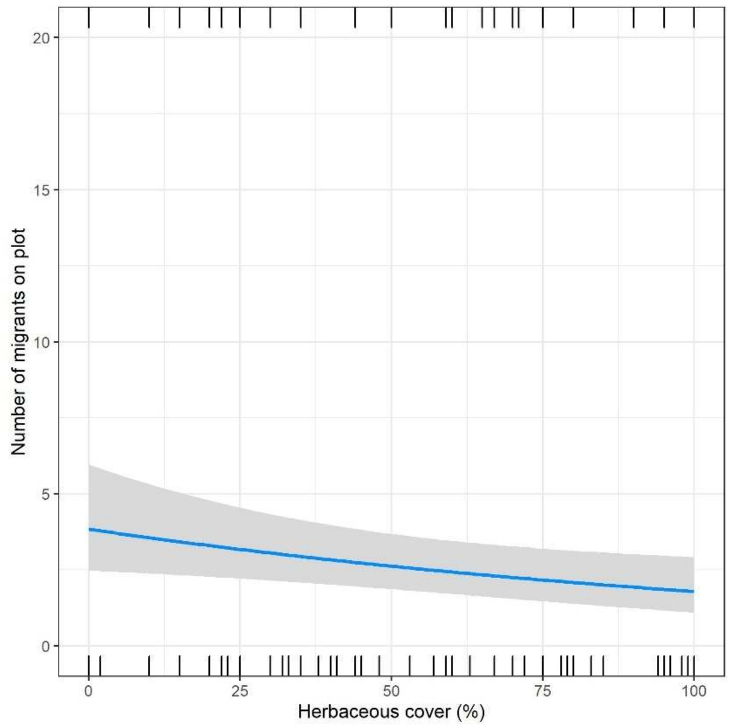


Figure N-6: Relationship between the area of plot covered by herbaceous vegetation and number of detected neotropical migrants on random plots. The blue line is the model prediction, the gray area is the 95% confidence interval.

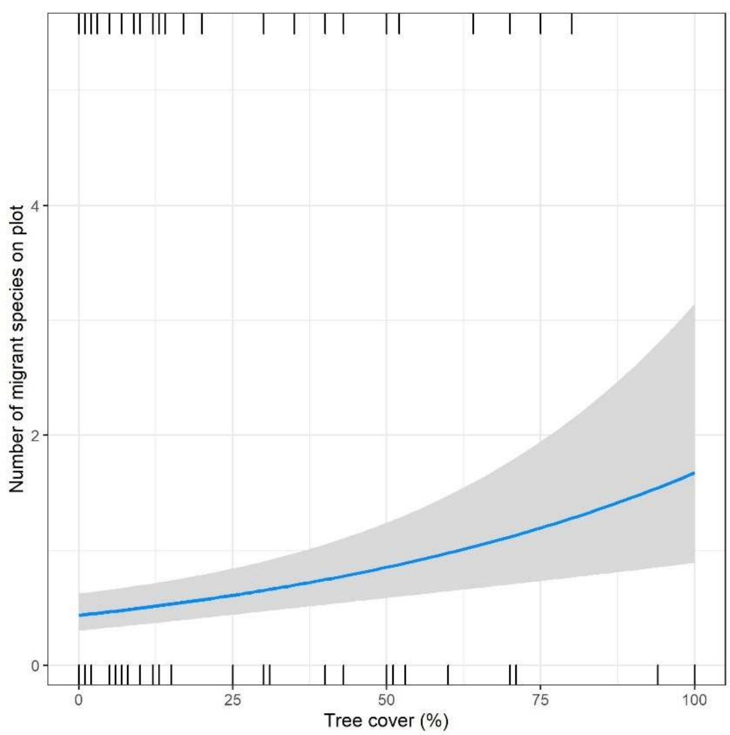


Figure N-7: Relationship between the area of plot covered by trees and species richness of neotropical migrants on random plots. The blue line is the model prediction, the gray area is the 95% confidence interval.

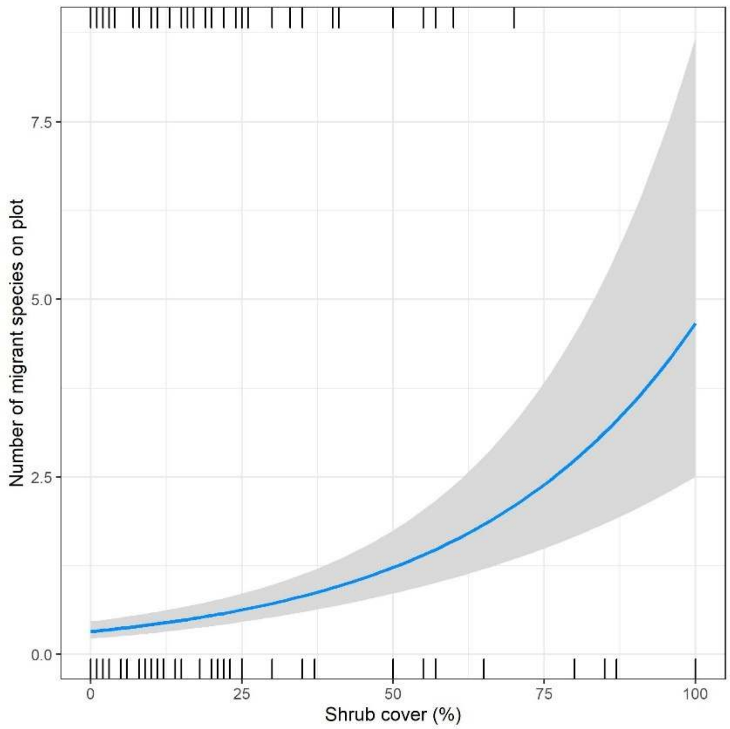


Figure N-8 Relationship between the area of plot covered by shrubs and species richness of neotropical migrants on random plots. The blue line is the model prediction, the gray area is the 95% confidence interval.

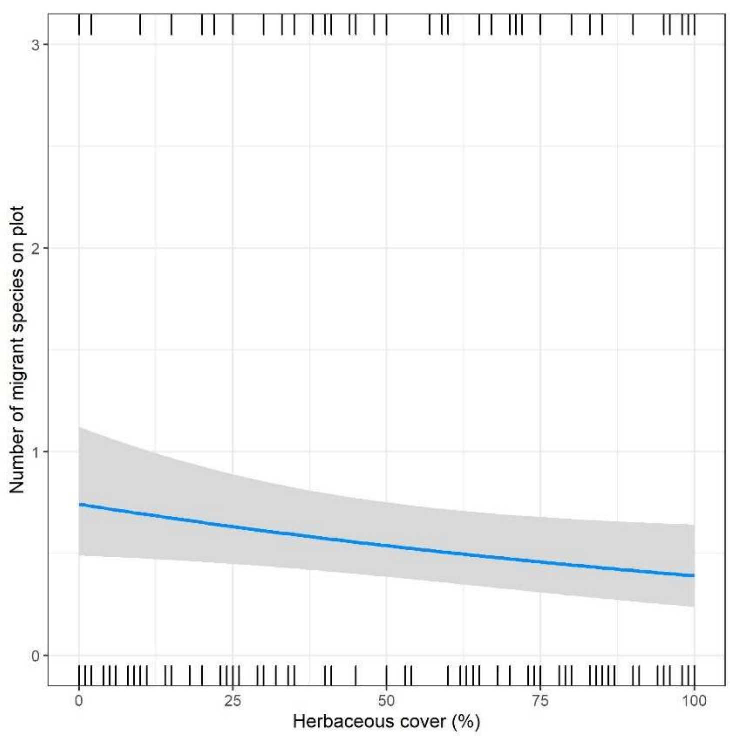


Figure N-9 Relationship between the area of plot covered by herbaceous vegetation and species richness of neotropical migrants on random plots. The blue line is the model prediction, the gray area is the 95% confidence interval.

The relationship between vegetation cover on plot and abundance of migrants varied based on individual species preferences. To illustrate this, the relationship between area of plot covered by trees, shrub, and herbaceous vegetation and abundance of all wood-warblers, all sparrows, and Common Yellowthroat was examined.

Controlling for time after sunrise and year, percent of plot covered by shrubs had a significant positive effect on the abundance of wood-warblers on random plots. Presence of wood-warblers was positively affected by shrub cover (estimate (log) (95% CI) = 0.055 (0.034, 0.076); Figure N-10), but there was no effect on the number of warblers recorded. There was no significant effect of percent of tree cover or percent of herbaceous cover on plot on the abundance of wood-warblers on random plots.

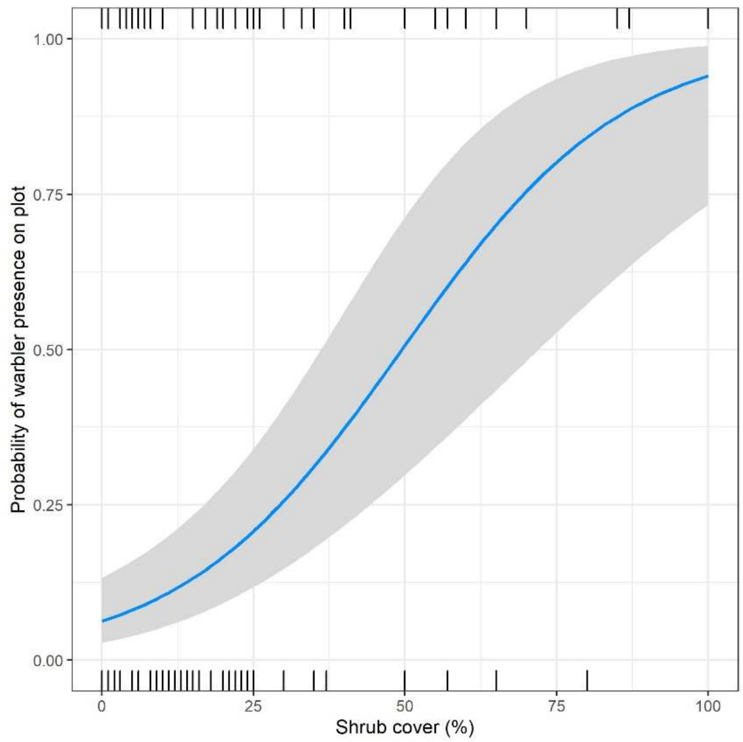


Figure N-10: Relationship between the area of plot covered by shrubs and probability of presence of wood-warblers on random plots. The blue line is the model prediction, the gray area is the 95% confidence interval.

Controlling for time after sunrise, the percent of plot covered by trees had a marginally significant negative effect on the presence of sparrows on random plots (estimate (Log) = -0.023 (-0.049, 0.003); Figure N-11), but the number of individuals was not affected. Percent of herbaceous cover on plot had a significant positive effect on sparrow presence on random plots (estimate (Log) = 0.017 (0.003, 0.030); Figure N-12), but number of individuals was not affected. There was no significant effect between percent of shrub cover on plot and the abundance of sparrows on random plots.

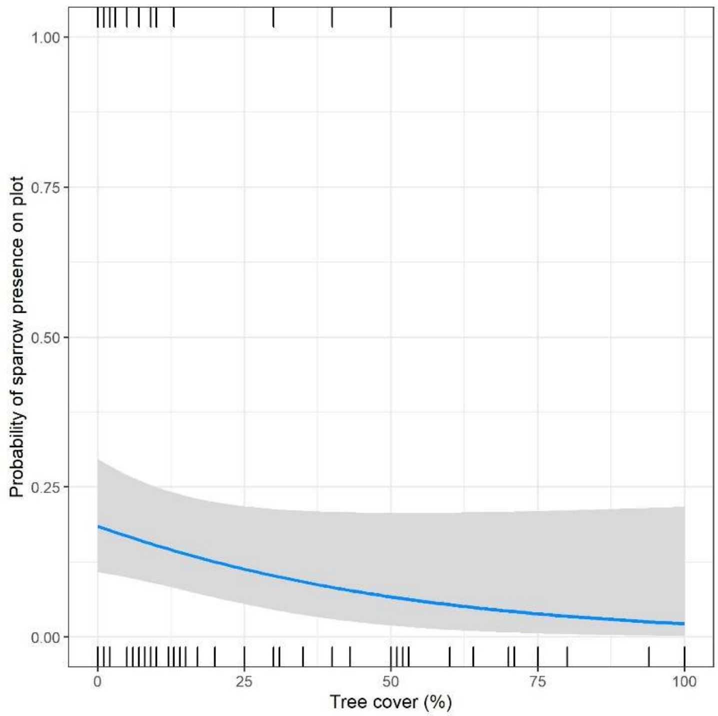


Figure N-11: Relationship between the area of plot covered by trees and probability of presence of sparrows on random plots. The blue line is the model prediction, the gray area is the 95% confidence interval.

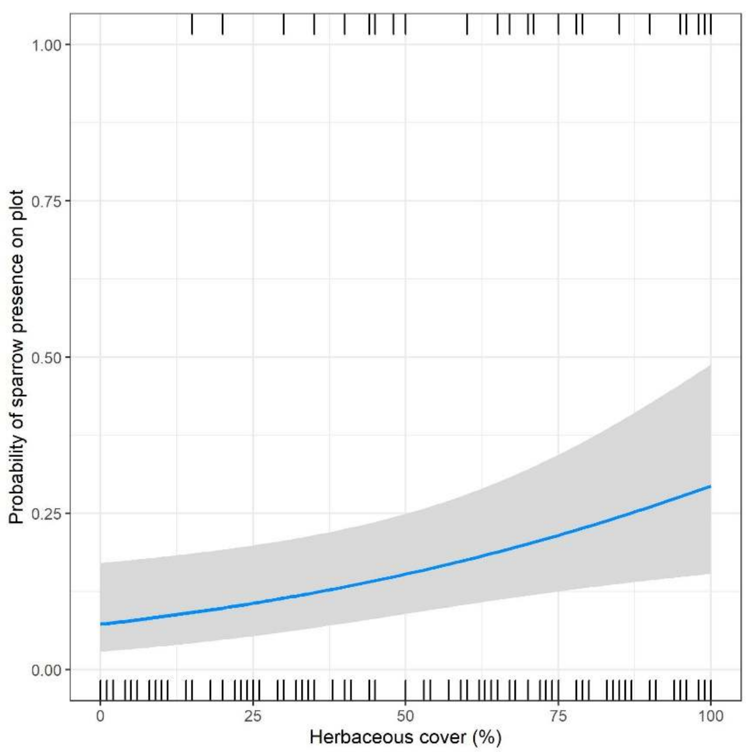


Figure N-12: Relationship between the area of plot covered by herbaceous vegetation and probability of presence of sparrows on random plots. The blue line is the model prediction, the gray area is the 95% confidence interval.

Controlling for time after sunrise, the probability of presence of Common Yellowthroat on random plots was marginally positively affected by the percent of plot covered by herbaceous cover (estimate (Log) = 0.011842 (-0.002, 0.025); Figure N-13) and marginally negatively affected by the percent of tree cover (estimate (Log) = -0.038 (-0.077, 0.001); Figure N-14). There was no significant effect of the percent of shrub cover and the abundance of Common Yellowthroats on random plots.

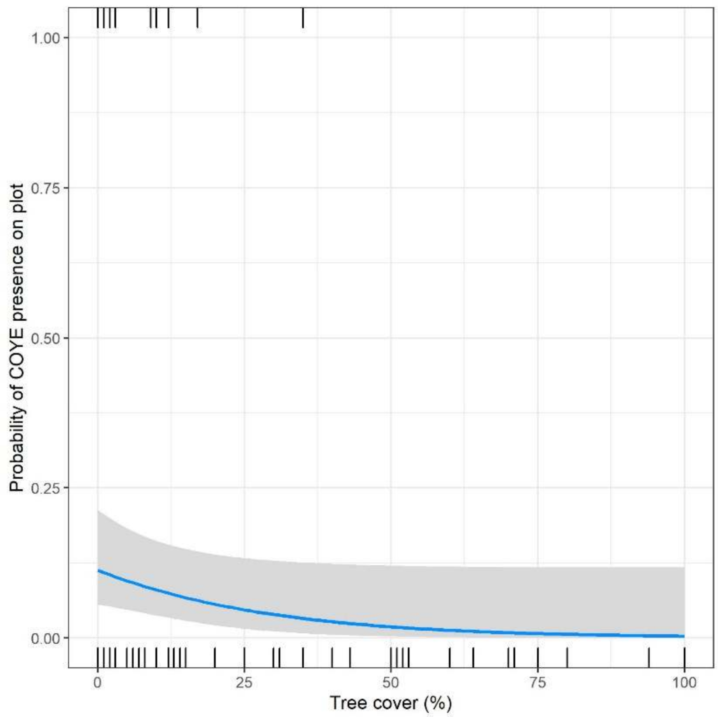


Figure N-13: Relationship between the area of plot covered by trees and probability of presence of Common Yellowthroat on random plots. The blue line is the model prediction, the gray area is the 95% confidence interval.

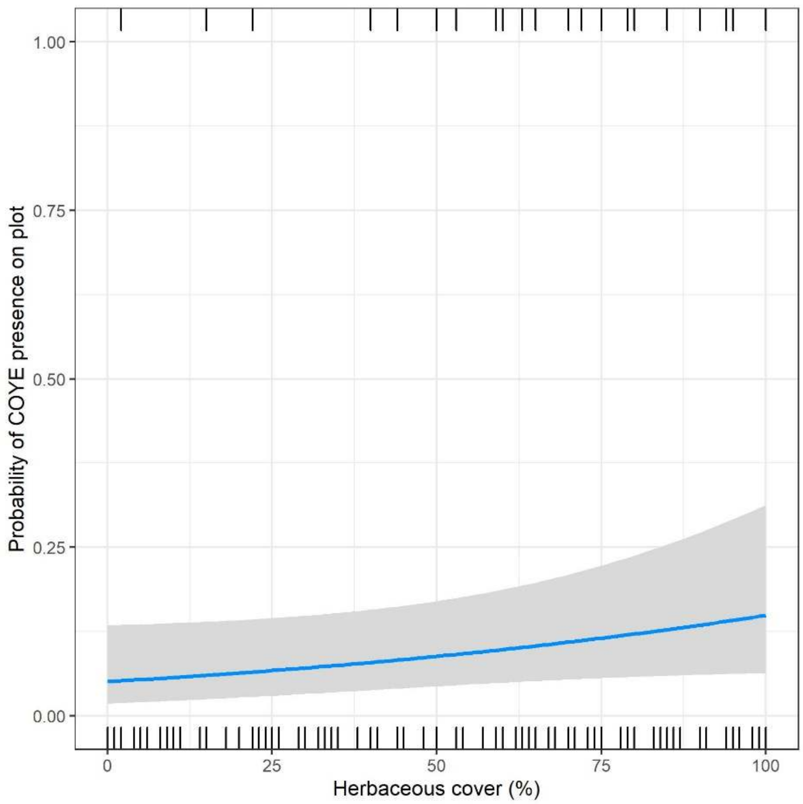


Figure N-14: Relationship between the area of plot covered by herbaceous vegetation and probability of presence of Common Yellowthroat on random plots. The blue line is the model prediction, the gray area is the 95% confidence interval.

Discussion: Due to the robust sample size of random plots, the estimates are likely representative. Results for Common Yellowthroat, wood-warblers, and sparrows are in accordance with the known habitat preferences of these species/families (Campbell et al. 2001).

Appendix O. Assessing neotropical migrant abundance and species richness in different habitat strata during spring migration.

Introduction: This analysis was conducted to assess variation in spring neotropical migrant abundance and species richness among broad habitat strata in Revelstoke Reach.

Methods: As a first step, random plots were assigned to habitat strata based on the vegetation collected on plot after each survey. Random plots were assigned into four habitat strata using the following criteria:

Forest stratum = tree cover ≥ 5%

Shrub stratum = tree cover < 5% and shrub cover ≥ 5%

Grassland stratum = tree cover < 5% and shrub cover < 5% and herbaceous cover ≥ 5%

Unvegetated stratum = tree cover < 5% and shrub cover < 5% and herbaceous cover < 5%

In total, 162 plots were assigned to forest strata, 163 to shrub strata, 303 to grassland strata, and 59 to unvegetated strata.

Dataset: Dataset #7, which contained data from the random plot surveys conducted during seven years of CLBMON-11B2 monitoring (2009 to 2014 and 2016), was used for this analysis. Plots covered by water with no available vegetation and plots with no habitat data were excluded. In case of duplicate surveys of the same plot, only the first survey was retained. Only records of migrants on plots were included. This dataset contains data from surveys of 687 random plots (144 plots in 2009, 39 in 2010, 66 in 2011, 120 in 2012, 105 in 2013, 119 in 2014, and 94 in 2016). In total, 1458 records of 51 neotropical migrant species were documented on plot. Mean abundance is reported (± SD), in units of birds per plot per survey (30 minutes); plots were 50 m x 50 m.

Analysis: Due to non-normality of the data (both for abundance and species richness), a Kruskal-Wallis test was used to investigate differences in abundance and species richness among broad habitat strata. Post-hoc Mann-Whitney tests with a Bonferroni correction were used to reveal the differences within groups.

Results: The abundance and species richness of spring migrants varied among strata (Table O-1, Figure 7). The abundance of migrants on plot was significantly different among strata (Kruskal-Wallis: $\chi^2(3) = 130.0$, $p < 0.001$). Forest plots had significantly higher abundance than grassland plots ($p < 0.001$, $r = 0.45$), shrub plots ($p = 0.02$, $r = 0.16$), and unvegetated plots ($p < 0.001$, $r = 0.49$). Similarly, shrub plots had significantly higher abundance than grassland ($p < 0.001$, $r = 0.31$) and unvegetated plots ($p < 0.001$, $r = 0.39$). In addition, grassland plots had higher abundance than unvegetated plots ($p = 0.03$, $r = 0.14$).

Table O-1: Abundance and species richness of spring neotropical migrant songbirds on random plot by broad habitat strata.

Habitat Strata	No. of Plots	Abundance		Species Richness	
		Mean	SD	Mean	SD
Grassland	303	0.91	3.44	0.33	0.72
Shrub	163	2.36	4.75	0.95	1.26
Forest	162	4.67	9.23	1.73	1.93
Unvegetated	59	0.32	1.64	0.07	0.25

Similar to abundance, the species richness of migrants was also significantly different among strata (Kruskal-Wallis: $\chi^2(3) = 140.2$, $p < 0.001$). Forest plots had significantly higher species richness than grassland plots ($p < 0.001$, $r = 0.47$), shrub plots ($p = 0.001$, $r = 0.21$) and unvegetated plots ($p < 0.001$, $r = 0.51$). Shrub plots had significantly higher species richness than grassland ($p < 0.001$, $r = 0.31$) and unvegetated plots ($p < 0.001$, $r = 0.41$). Grassland plots had higher species richness than unvegetated plots ($p = 0.02$, $r = 0.17$).

Comments: This analysis described the habitat use by fall migrants reasonably accurately and in accordance with expectations. Despite large within-group variation, the differences between groups were significant. All strata were sampled with enough replications to account for variability in annual, seasonal, and time-of-day variation in bird presence and activity.

Appendix P. Assessing abundance and species richness of spring neotropical migrants in different habitat types.

Introduction: This analysis was conducted to assess variation in spring neotropical migrant abundance and species richness among habitat types in Revelstoke Reach.

Methods: Plots were assigned to habitat type (Appendix D) based on CBA habitat mapping (CBA 2016b). Each plot was assigned to the dominant habitat type on plot (excluding open water).

Dataset: The analysis was completed using dataset #7, which contained data from the random plot surveys conducted during seven years of the CLBMON-11B2 monitoring (2009 to 2014 and 2016). Plots covered by water with no available vegetation, and plots with no habitat data were excluded. In case of duplicate surveys of the same plot, only the first survey was retained. Only records of migrants on plots were included. This dataset contains data from surveys of 687 random plots (144 plots in 2009, 39 in 2010, 66 in 2011, 120 in 2012, 105 in 2013, 119 in 2014, and 94 in 2016). In total, 1,458 records of 51 neotropical migrant species were documented on plot. Mean abundance is reported (± SD), in units of birds per plot per survey (30 minutes); plots were 50 m x 50 m.

Analysis: The density of migrants for each habitat type was calculated based on the average abundance of migrants on plots assigned to that habitat type (pooled data from all years). Heat maps were produced by intersecting the habitat type map with a 50x50 m grid, then dissolving the polygons. The value of each of these 50x50 m cells is an average of the underlying density values from the habitat type within the cell.

Results: The abundance and diversity of spring migrants varied among habitat types (Table P-1). Of the 25 habitat types surveyed (687 random plots), riparian forest habitat had the highest average abundance of migrants per survey (5.2 ± 10.79 birds/survey; n = 46), followed by cattail habitat (5.0 ± 0 birds/survey; n = 2), upland forest habitat (4.8 ± 10.20 birds/survey; n = 24), swamp habitat (4.2 ± 6.06 birds/survey; n = 15), and shrub savannah habitat (3.5 ± 7.82 birds/survey; n = 153) (Table P-1).

Species richness was highest at plots in cattail habitat (2.5 ± 0.71 species/survey; n = 2), followed by riparian forest habitat (1.9 ± 2.11 species/survey; n = 46), floating bog habitat (1.7 ± 1.38 species/survey; n = 7), swamp habitat (1.6 ± 1.54 species/survey, n = 15), and upland forest habitat (1.6 ± 1.56 species/survey; n = 24) (Table P-1).

A map of modelled overall neotropical migrant density and species richness in Revelstoke Reach during spring migration is provided in Figure 8 and Figure P-1, respectively.

Table P-1: **Abundance and species richness of spring neotropical migrants on random plots by habitat type.**

Habitat Type		Code	No. of Plots	Abundance		Species Richness	
				Mean	SD	Mean	SD
Forest	Riparian forest	RF	46	5.17	10.79	1.87	2.11
	Upland forest	UF	24	4.79	10.20	1.58	1.56
Grassland	Horsetail grassland	EG	17	0.12	0.33	0.12	0.33
	Mixed grassland	MG	83	0.83	2.18	0.42	0.89
	Sparse grassland	PG	21	0.52	1.21	0.33	0.73
	Reed canary grass	RC	17	0.82	1.70	0.35	0.79
	Sedge grassland	SG	42	1.55	5.94	0.31	0.60
Shrub	Shrub savannah	SH	153	3.50	7.82	1.20	1.76
	Riparian shrub	SR	17	1.59	1.54	1.00	0.94
Unvegetated	Rocky bank	RB	7	2.29	4.39	1.00	1.53
	Thalweg	TH	30	0.57	2.21	0.20	0.48
	Gravel	GR	17	0.47	1.18	0.24	0.56
	Sand	SA	19	0.42	0.90	0.26	0.56
	Sand bank	SB	2	0.50	0.71	0.50	0.71
	Silt	SI	12	1.00	3.46	0.08	0.29
Wetland	Floating bog	BF	7	2.57	1.99	1.71	1.38
	Bulrush	BR	10	1.20	1.23	1.00	1.05
	Submerged buoyant bog	BS	7	1.43	2.51	1.00	1.41
	Creek	CK	12	0.75	1.29	0.50	0.80
	Cattail	CT	2	5.00	0.00	2.50	0.71
	Low elevation draw	LD	23	2.22	5.05	0.52	0.90
	Pond	PO	55	1.04	2.41	0.51	0.98
	Swamp	SW	15	4.20	6.06	1.60	1.54
	Wet meadow	WM	29	0.97	2.76	0.28	0.59
	Water sedge	WS	20	2.00	3.15	0.85	1.31

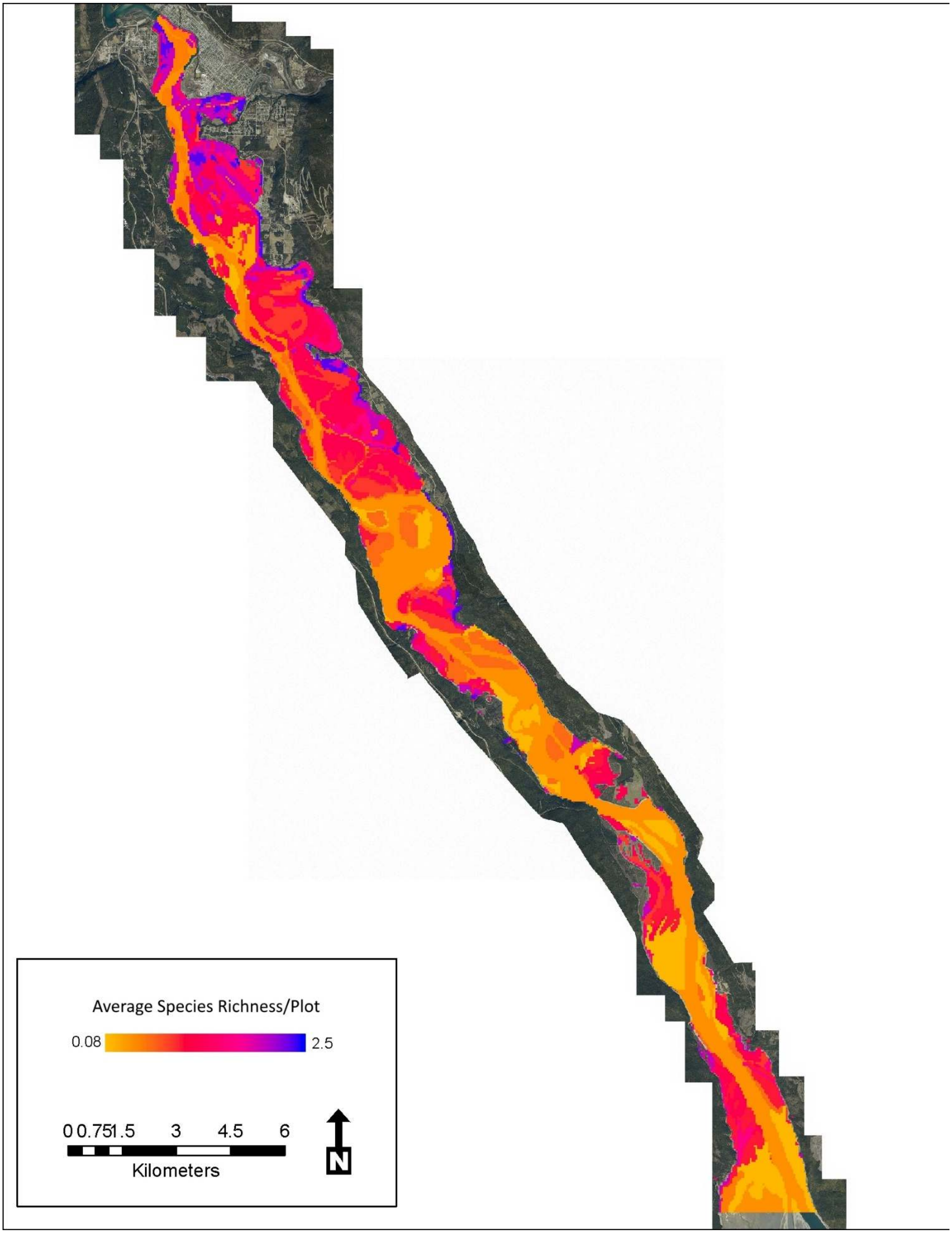


Figure P-1: Map of modelled neotropical migrant songbird species richness in Revelstoke Reach during spring migration (pooled data from all species are plotted).

Comments: The large sample size allowed for estimation of migrant abundance and species richness reasonably well for dominant habitat types in the drawdown zone (e.g., mixed grassland, sparse grassland, sedge-grassland, shrub-savannah, riparian forest). For these, stratified random sampling allowed for a reasonably wide annual, seasonal, and time-of-day sampling variability. Estimates for all sampled habitat types were included, but the sample size for some of them was very small. As such, care must be taken in interpreting these results. Moreover, it is important to note that the vegetation communities were assigned based on the dominant habitat type on plot and in some cases the bird observation could be biased by the presence of a patch of very attractive or unsuitable habitat on a plot, especially if the sample size is small. However, the habitat types with small samples are, for the most part, the ones that are very localized and cover only very small (less than 1%) area in the drawdown zone. All of the estimations are presented, but caution should be used when generalizing results of habitat types with a small sample size.

Appendix Q. Assessing variation of abundance of three families of migrants by strata and vegetation type during spring migration.

Introduction: This analysis was conducted to assess variation of abundance of three main families of migrants in Revelstoke Reach during fall migration by broad strata and habitat type.

Dataset: Dataset #7 was used for this analysis of bird detections during random plot surveys (Section 3.4) conducted over seven years (CLBMON-11B2; 2009 to 2014 and 2016). Plots covered by water with no available vegetation and plots with no habitat data were excluded. In case of duplicate surveys of the same plot, only the first survey was retained. Only records of migrants on plots were included (i.e., migrants recorded outside plots were excluded). This dataset contains data from surveys of 687 random plots (144 plots in 2009, 39 in 2010, 66 in 2011, 120 in 2012, 105 in 2013, 119 in 2014, and 94 in 2016). In total, 1,458 records of 51 neotropical migrant species were documented on plot. Mean abundance is reported (± SD), in units of birds per plot per survey (30 minutes); plots were 50 m x 50 m.

For this analysis, three main families of migrants in Revelstoke Reach were analyzed separately: flycatchers (Tyrannidae), wood-warblers (Parulidae), and sparrows (Passerellidae). In addition, the habitat preferences of American Pipit and Yellow-rumped Warbler were examined, since they are two of the dominant species of migrants during spring migration.

Analysis: The density of each migrant family for each habitat type was calculated based on the average abundance of these migrants on plots assigned to that habitat type (pooled data from all years). Heat maps were produced by intersecting the habitat type map with a 50x50 m grid, then dissolving the polygons. The value of each of these 50x50 m cells is an average of the underlying density values from the habitat type within the cell.

Results: Flycatchers and wood-warblers had the highest average abundance on plots in forest habitat (0.17 ± 0.46 birds/survey and 1.65 ± 4.40 birds/survey, respectively, n = 162). Sparrows had the highest average abundance on plots from shrub habitat strata (0.69 ± 1.82 birds/survey, n = 163). American Pipit had the highest average abundance on grassland plots (0.36 ± 2.92, n = 303), closely followed by unvegetated plots (0.32 ± 1.64, n = 59). Yellow-rumped Warbler had the highest average density on forested plots (0.93 ± 3.97, n = 162) (Table Q-1).

Table Q-1: Abundance of flycatchers, wood-warblers, sparrows, American Pipit (AMPI), and Yellow-rumped Warbler (YRWA) on random plots during spring migration by broad habitat strata.

Habitat Strata	No. of Plots	Flycatchers		Warblers		Sparrows		AMPI		YRWA	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Grassland	303	0.01	0.16	0.08	0.43	0.14	0.40	0.36	2.92	0.04	0.29
Shrub	163	0.04	0.22	0.73	2.48	0.69	1.82	0.13	1.14	0.44	2.17
Forest	162	0.17	0.46	1.65	4.40	0.35	0.91	0.20	2.51	0.93	3.97
Unvegetated	59	.	.	.	.	.	.	0.32	1.64	.	.

The average abundance of wood-warblers, sparrows, American Pipit, and Yellow-rumped Warbler varied among habitat types (Table Q-2). The abundance of wood-warblers (and also Yellow-rumped Warbler) was highest in upland forest (3.3 ± 9.69 birds/survey and 2.96 ± 9.12, respectively; n = 24), and the abundance of sparrows was highest in cattail habitat (2.0 ± 2.83 birds/survey; n = 2). American Pipit, the most abundant spring migrant in Revelstoke Reach, had the highest abundance in sedge grassland habitat (1.36 ± 5.75 birds/survey; n = 42). A map of modelled density of two groups of migrants (flycatchers, wood-warblers), American Pipit, and Yellow-rumped Warbler during spring migration in Revelstoke Reach is provided in Figure Q-1.

Table Q-2: Abundance of wood-warblers, sparrows, American Pipit (AMPI) and Yellow-rumped Warbler (YRWA) on random plots during spring migration by habitat type.

Habitat Type		No.	Warblers		Sparrows		AMPI		YRWA	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD
Forest	Riparian forest	46	1.39	2.32	0.41	1.39	0.70	4.72	0.57	1.50
	Upland forest	24	3.33	9.69	0.21	0.51	.	.	2.96	9.12
Grassland	Horsetail grassland	17	.	.	0.12	0.33	.	.	.	.
	Mixed grassland	83	0.16	0.72	0.31	0.99	0.01	0.11	0.07	0.46
	Sparse grassland	21	.	.	0.19	0.51	.	.	.	.
	Reed canary grass	17	0.06	0.24	0.06	0.24	.	.	0.06	0.24
	Sedge grassland	42	0.05	0.22	0.10	0.30	1.36	5.75	.	.
Shrub	Shrub savannah	153	1.06	3.00	0.55	1.63	0.18	2.18	0.47	2.38
	Riparian shrub	17	0.59	1.23	0.35	0.70	.	.	0.41	0.87
Unvegetated	Rocky bank	7	0.71	1.50	.	.	.	.	0.14	0.38
	Thalweg	30	0.43	2.19	0.07	0.25	0.03	0.18	0.40	2.19
	Gravel	17	0.18	0.73	0.12	0.33	0.18	0.73	0.18	0.73
	Sand	19	0.05	0.23	0.05	0.23	0.16	0.69	0.05	0.23
	Sand bank	2	.	.	.	.	0.50	0.71	.	.
	Silt	12	.	.	.	.	1.00	3.46	.	.
Wetland	Floating bog	7	1.29	1.11	1.00	1.41	.	.	0.57	1.13
	Bulrush	10	0.20	0.42	0.10	0.32	.	.	0.10	0.32
	Submerged buoyant bog	7	.	.	0.29	0.49	.	.	.	.
	Creek	12	.	.	0.50	1.24	.	.	.	.
	Cattail	2	1.00	0.00	2.00	2.83	.	.	0.50	0.71
	Low elevation draw	23	0.22	0.74	0.39	1.37	0.91	4.38	0.22	0.74
	Pond	55	0.24	0.67	0.15	0.45	0.02	0.13	0.22	1.37
	Swamp	15	0.73	1.16	0.93	1.28	.	.	0.07	0.26
	Wet meadow	29	0.14	0.58	0.07	0.26	0.76	2.64	0.10	0.41
	Water sedge	20	0.55	1.50	0.05	0.22	0.05	0.22	0.30	1.34

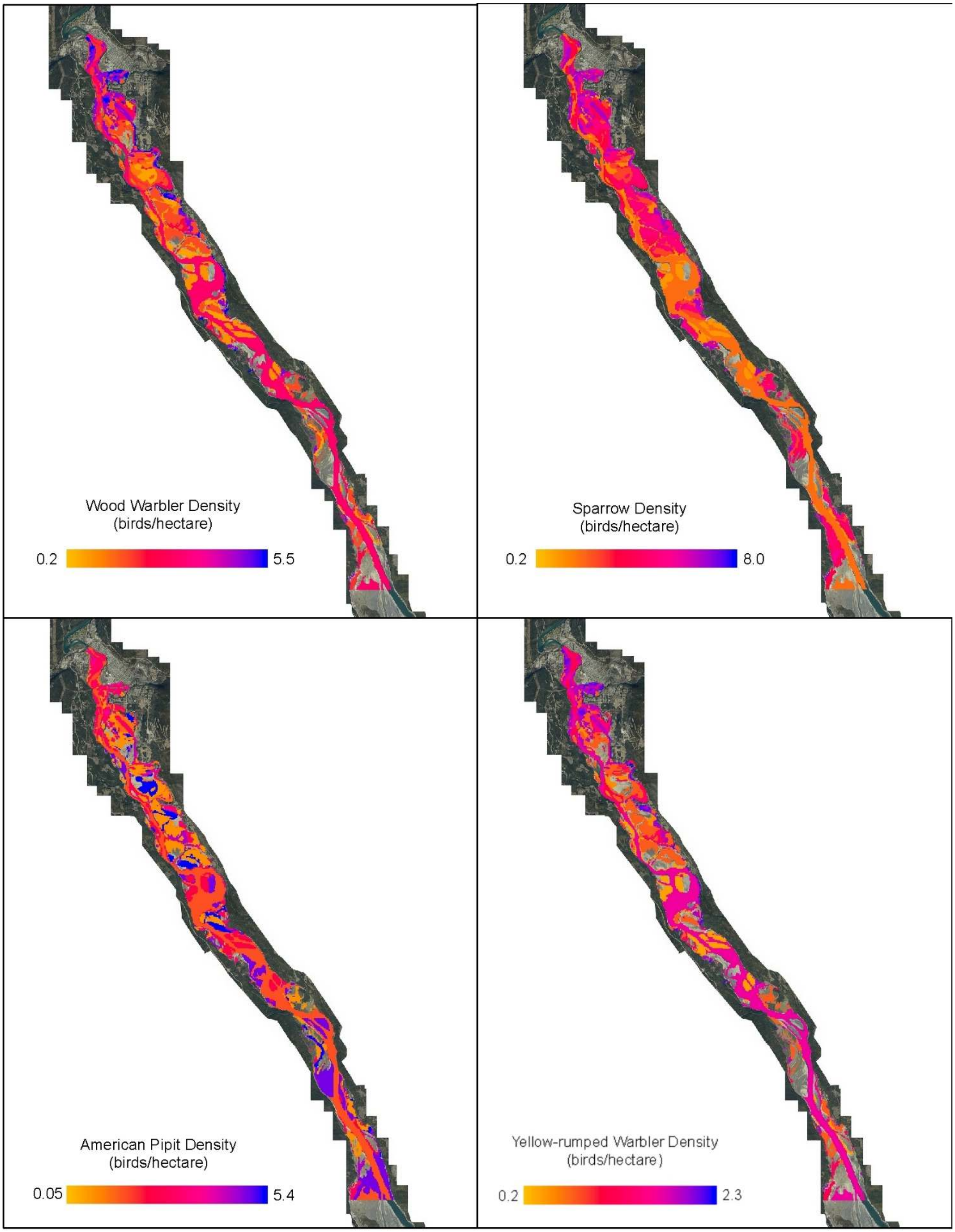


Figure Q-1: Map of modelled density of wood-warblers, sparrows, American Pipit, and Yellow-rumped Warbler in Revelstoke Reach during spring migration.

Comments: While pooling all species together allowed for the estimation of overall abundance and species richness in different habitats, not all species had the same habitat preferences. Robust sample sizes for each broad habitat strata allowed for reasonably accurate estimates of abundance and species richness. For habitat type, estimates should be interpreted with caution because: (1) small sample size of some habitat types, and (2) habitat type was assigned based on dominant vegetation community on plot. As such, bird abundance and species diversity may be biased by the presence of a small area of high quality or inappropriate habitat on those plots.

Appendix R. Assessing variation in abundance and species richness of spring migrants based on vegetation cover.

Introduction: This analysis was conducted to assess variation of spring neotropical migrant abundance and species richness in Revelstoke Reach based on vegetation cover.

Methods: Habitat data collected on random plots after each survey was used to assign forest, shrub, and herbaceous vegetation cover to each random plot.

Dataset: Dataset #7, which contained data from the random plot surveys conducted during seven years of the CLBMON-11B2 monitoring (2009 to 2014 and 2016), was used for this analysis. Plots covered by water with no available vegetation and plots with no habitat data were excluded. In case of duplicate surveys of the same plot, only the first survey was retained. Only detections of neotropical migrants observed to be perched or moving within plot habitat were included. This dataset contains data from surveys of 687 random plots (144 plots in 2009, 39 in 2010, 66 in 2011, 120 in 2012, 105 in 2013, 119 in 2014, and 94 in 2016). In total, 1,458 records of 51 neotropical migrant species were documented on plot.

Analysis: This analysis examined the effect of vegetation cover (forest, shrub, and herbaceous cover) on abundance and species richness of neotropical migrants on random plots. Due to a high number of zeroes (plots with no birds detected) in the dataset, a hurdle model structure from the ‘pscl’ package within R statistical framework (Zeileis et al. 2008, Jackman 2017) was used to model migrant abundance on plot. In these models, binomial distribution was used to model the hurdle component of zero counts and a negative binomial distribution was used to model the truncated count component. Models with a negative binomial distribution in the count component fit data better and received more support than models with a Poisson distribution. Species richness on plot was modeled using generalized linear models (GLM) with a negative binomial distribution, which fit data better than a Poisson distribution. R package MASS was used to run the GLM models (Venables and Ripley 2002).

First, univariate models were used to confirm the relationship between abundance and species richness of migrants on plot and three temporal variables that were previously found to influence neotropical abundance in the Revelstoke Reach: (1) time of day when the survey was initiated, (2) day of the year when the survey was conducted (Julian date), and (3) year to account for annual differences in migrant abundance and reservoir operations. In the final models, controlling for significant temporal variables, the abundance of migrants (or species richness) on plot was modelled as a function of tree/shrub/herbaceous cover on plot. Estimates from all the models are presented on logit scale (presence) or log scale (count and species richness) and likelihood-based confidence intervals were calculated using the MASS package (Venables and Ripley 2002). R package visreg (Breheny and Burchett 2017) was used to transform and visualize fitted relationships on the original scale.

Results: The presence of migrants on plots was positively affected by Julian date (estimate (Log odds) (95% CI) =0.013 (0.004, 0.023), but count was marginally negatively affected (estimate (Log) = -0.015 (-0.029, -0.000)). It was independent of time since sunrise, and varied slightly among years.

Controlling for Julian date and year, tree cover (percent of plot covered by trees) had a significant positive effect on the presence of migrants on plot (estimate (95% CI) = 0.034 (0.023, 0.044); Figure R-1) but no effect on the number of observed migrants on plot.

Controlling for Julian date and year, shrub cover (percent of plot covered by shrubs) had a significant positive effect on the presence of migrants on plot (estimate (Log odds) (95% CI) = 0.051 (0.040, 0.063); Figure R-2), but was independent of the number of observed migrants.

Controlling for time after sunrise and year, herbaceous cover (percent of plot covered by herbaceous vegetation) did not have an effect on the abundance of migrants on plot (Figure R-3).

The species richness of migrants on plots varied among years, was negatively affected by time since sunrise (estimate (Log) (95% CI) = -2.305 (-3.745, -0.884) and was positively affected by Julian date (estimate (Log) = 0.021 (0.013, 0.029)).

Controlling for time after sunrise, Julian date and year, the species richness of neotropical migrants was positively affected by tree cover (estimate (Log) = 0.022 (0.016, 0.028); Figure R-4) and shrub cover (estimate (Log) = 0.029 (0.023, 0.035), Figure R-5). However, herbaceous cover had no effect on species richness (Figure R-6).

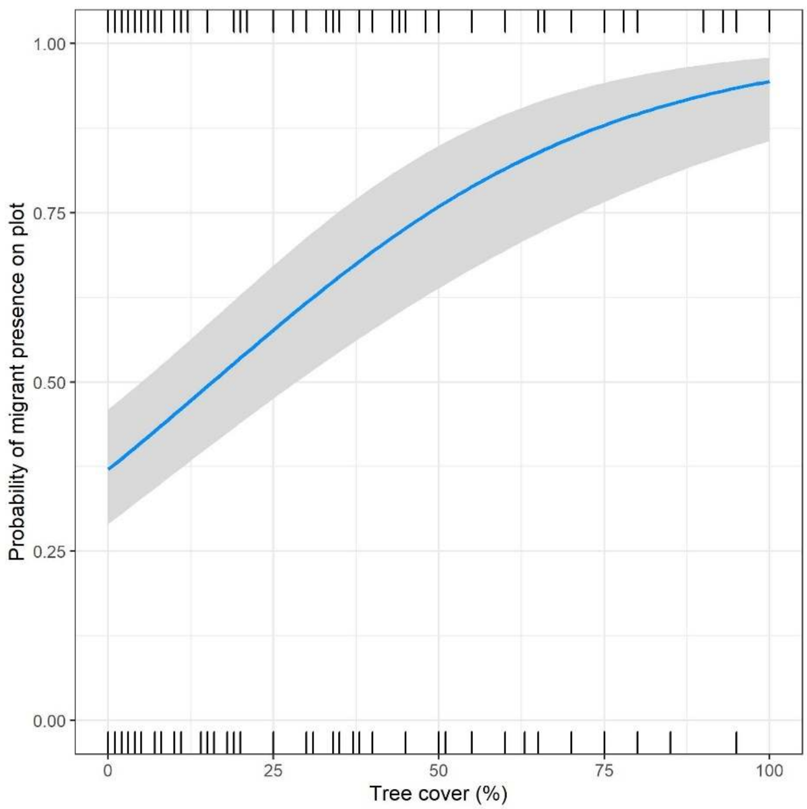


Figure R-1: Relationship between the area of plot covered by trees and probability of neotropical migrant presence on random plots. The blue line is the model prediction, the gray area is the 95% confidence interval.

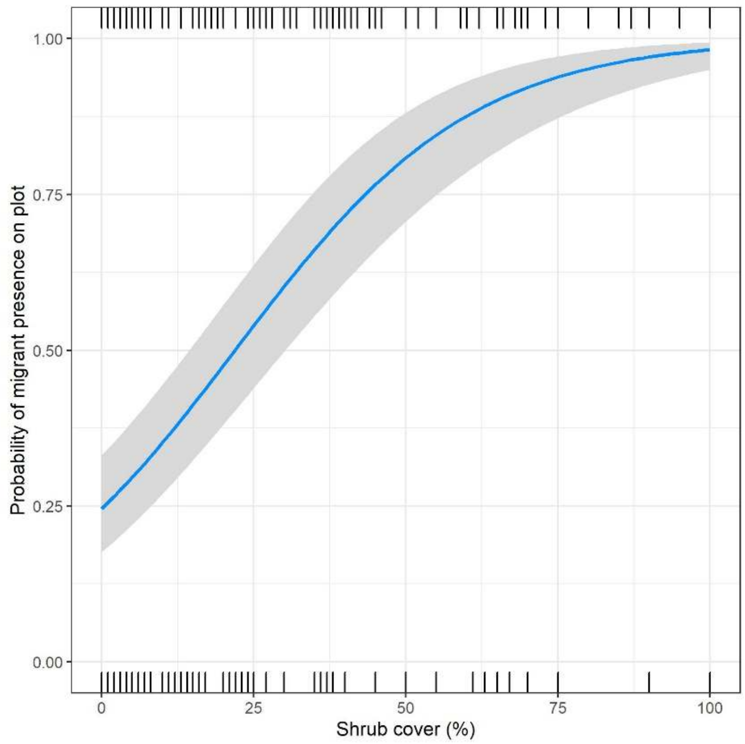


Figure R-2: Relationship between the area of plot covered by shrubs and probability of neotropical migrant presence on random plots. The blue line is the model prediction, the gray area is the 95% confidence interval.

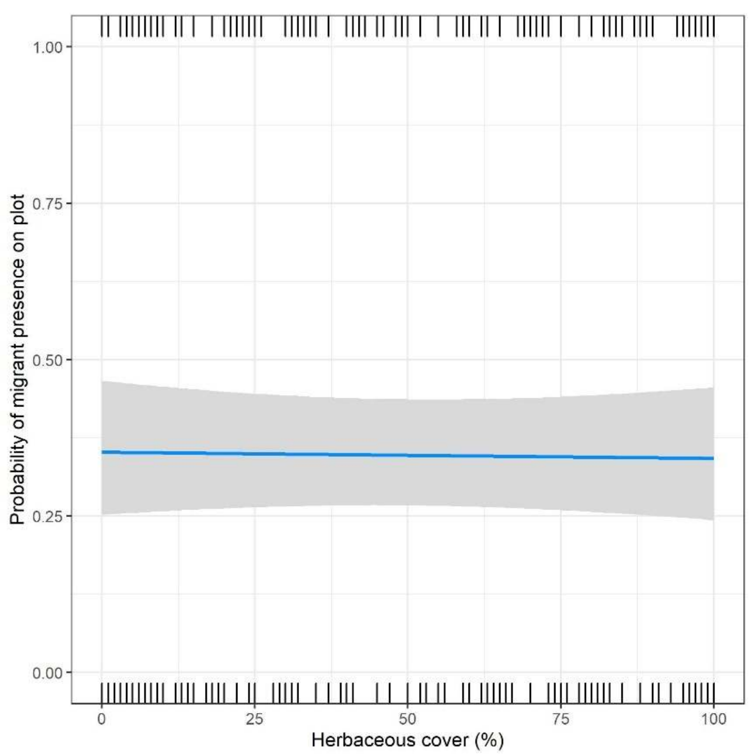


Figure R-3: Relationship between the area of plot covered by herbaceous vegetation and probability of neotropical migrant presence on random plots. The blue line is the model prediction, the gray area is the 95% confidence interval.

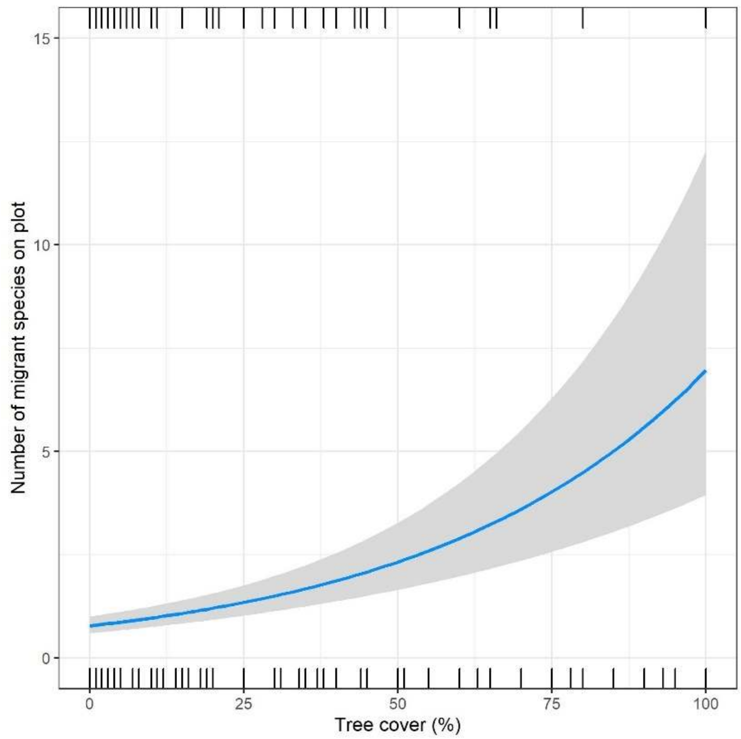


Figure R-4: Relationship between the area of plot covered by trees and species richness of neotropical migrants on random plots. The blue line is the model prediction, the gray area is the 95% confidence interval.

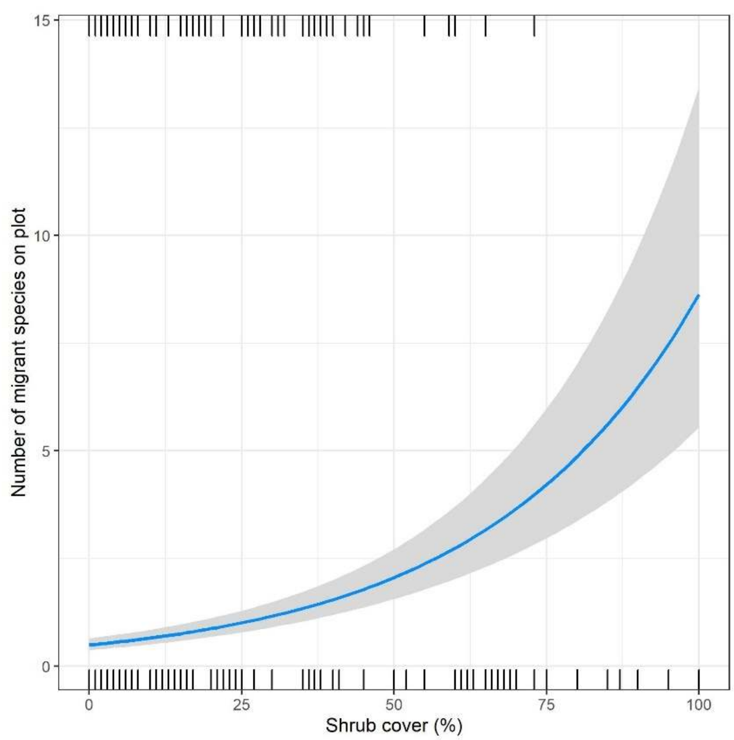


Figure R-5: Relationship between the area of plot covered by shrubs and species richness of neotropical migrants on random plots. The blue line is the model prediction, the gray area is the 95% confidence interval.

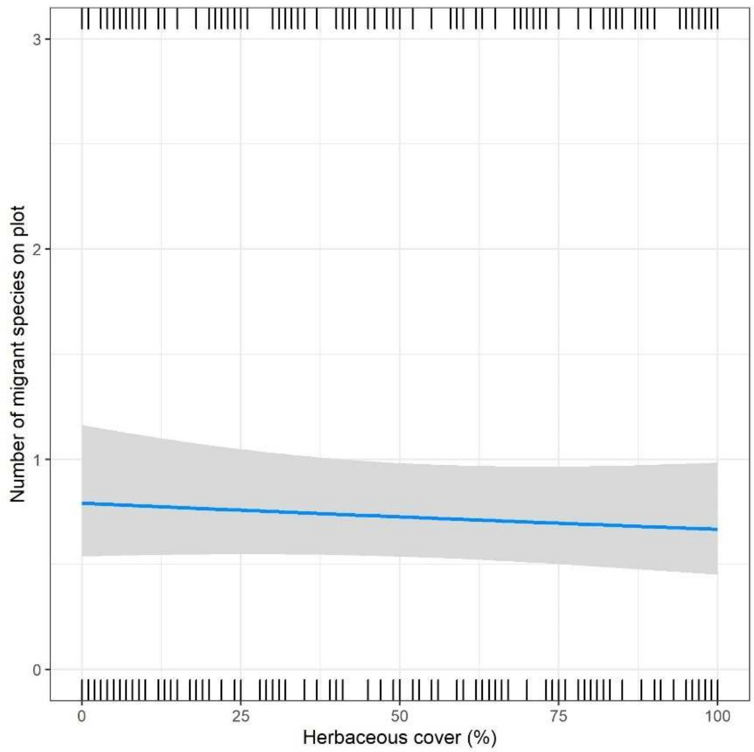


Figure R-6: Relationship between the area of plot covered by herbaceous vegetation and species richness of neotropical migrants on random plots. The blue line is the model prediction, the gray area is the 95% confidence interval.

Comments: Due to the robust sample size of random plots, the estimates are likely representative. Results for Common Yellowthroat, wood-warblers, and sparrows are in accordance with the known habitat preferences of this species/families (Campbell et al. 2001).

Appendix S. Assessment of the effects of reservoir operations on neotropical migrant abundance and species richness using banding station data.

Introduction: This analysis was conducted to assess the effect of reservoir operations on neotropical migrant abundance and species richness in Revelstoke Reach.

Methods: Banding station data collected at Machete Island, Airport Islands, and Jordan River banding stations were analyzed to reveal potential effects of reservoir operation on capture rate and species richness.

Dataset: Dataset #8 was used for this analysis which contained banding data for 430 surveys at three sites (Machete Island n=306, 10 years; Airport Island n=57, 7 years; and Jordan River n=67, 7 years). For analysis of species richness, a subset containing only surveys with effort of at least 24 net-hours was used. This subset contained 408 surveys (Machete Island n=288, Airport Islands n=53, Jordan River n=67).

Analysis of variation in capture rates among years: The average annual capture rates of newly-captured birds[1] were calculated for each station (total number of new captures/total number of net-hours). These annual summary statistics were plotted in relation to three annual measures of reservoir operation:

(1) maximal annual reservoir water level,
(2) reservoir water level on August 7, and
(3) the number of days in the January through September period with reservoir water level over 438 m.

Analysis of daily variation in capture rates and diversity: Daily capture rate and daily species richness were both calculated using all capture records (new captures and recaptures, but excluding same day recaptures). These values were examined in relation to the reservoir operation, which was characterized as:

(1) the water level at the banding site on the day of a survey, and
(2) whether the banding site (or part of it) had been flooded in the current year.

The water level at the banding station was calculated as average daily reservoir water elevation minus elevation of the lowest net line at the station, where negative values are corrected to zero. The effect of reservoir operation was assessed separately at the two banding stations located within the drawdown zone (Machete Island n=288 surveys, Airport Islands n=53 surveys; Appendix A). These stations were positioned at different elevations (Airport Islands was lower; Appendix A) relative to full pool level (440.1 m) and experienced different exposure to flooding; thus it could be expected that the effects of reservoir operations would be different at each station.

Daily capture rate values from Machete Island banding station were log-transformed prior to analysis so the data would conform with model assumptions of normality and heterogeneity.

Univariate linear models were used to confirm the effect of year and season (Julian date) on variation in capture rates and species richness at each station. The relationship between Julian date and capture rate (and species richness) was not linear, and inclusion of a quadratic term improved the model so the quadratic term was used in subsequent analyses to control for Julian date.

For each station, a set of candidate models was compared using Akaike's Information Criterion corrected for small sample size (AICc) to investigate whether inclusion of any measure of reservoir operations improved the prediction of daily capture rate or daily species richness

[1] New captures = new birds and first annual captures of birds banded in previous years

among years (Burnham and Anderson 2002). The relationship was visualized using the R packages ggplot2 (Wickham 2016) and visreg (Breheny and Burchett 2017).

Analysis of stopover length: In addition to capture rate and species richness, detailed capture-recapture data from Machete Island banding station during years of daily monitoring (2008 to 2010 and 2015 to 2017) allowed for examination of differences in stopover length of neotropical migrants among years.

Results: Variation in average annual capture rates did not show a clear relationship with any of the three annual measures of reservoir operations (Figure S-1).

At Machete Island banding station, daily capture rate (log transformed) varied among years ($F_{(9,296)} = 10.1$, $p < 0.001$) and throughout the season (Julian date (quadratic): $F_{(1,303)} = 69.3$, $p < 0.001$). Daily species richness also varied among years ($F_{(9,278)} = 5.3$, $p < 0.001$) and throughout the season (Julian date (quadratic): $F_{(1,285)} = 60.2$, $p < 0.001$). For both response measures, models were not improved with the inclusion of either measure of reservoir operations (Table S-1, Table S-2).

Table S-1: Comparison of support for models of daily capture rate at Machete Island banding station. Models are ranked according to the difference from the best model based on Akaike's Information Criterion corrected for small sample size (AICc). K is the number of model parameters and w_i is the Akaike weight.

Model	K	AICc	ΔAICc	w_i
Julian + Year	13	599.79	0	1
Julian	4	674.05	74.26	0
Julian + Water level	5	674.81	75.02	0
Julian + Flooded	5	675.74	75.95	0
Year	11	695.74	95.95	0
null	2	758.83	159.03	0

Table S-2: Comparison of support for models of daily species richness at Machete Island banding station. Models are ranked according to the difference from the best model based on Akaike's Information Criterion corrected for small sample size (AICc). K is the number of model parameters and w_i is the Akaike weight.

Model	K	AICc	ΔAICc	w_i
Julian + Year	13	1499.97	0	1
Julian + Water level	5	1537.57	37.60	0
Julian + Flooded	5	1541.81	41.84	0
Julian	4	1542.47	42.49	0
Year	11	1692.32	192.35	0
null	2	1719.33	219.35	0

In the univariate models at Airport Islands banding station, daily capture rate varied with season (Julian date (quadratic); $F_{(1,54)} = 6.5$, $p > 0.05$) and marginally among years ($F_{(6,50)} = 2.0$, $p = 0.08$). Among the candidate models, the best model of capture rate only considered Julian date (Table S-3). The inclusion of either of the measures of reservoir operations did not improve model performance.

In the univariate models, daily species richness varied among years at Airport Islands ($F_{(6,46)}$ = 2.5, p < 0.05), but did not vary not with season (Julian date (quadratic); $F_{(1,50)}$ = 0.7, p = 0.4). Among the candidate models, the model with daily water level (and 'Julian date') explained variation in daily species richness better than the base model with terms 'Julian date + Year' (Table S-4). Controlling for Julian date, daily water level on site tended to have a negative effect on daily species richness at Airport Islands banding station ($F_{(1,49)}$ = 3.5, p = 0.07).

For both capture rates and species richness at Airport Islands, candidate models containing reservoir operation variables were ranked close to the leading model (<2 AIC points; Table S-3, Table S-4), suggesting some support an effect of reservoir operations at this low elevation banding station.

Pooling data from all species together (n = 2,323), the stopover length was not significantly different among years (Kruskal-Wallis, $\chi^2(5)$ = 9.66, p = 0.09; Figure S-2).

Table S-3: Comparison of support for models of daily capture rate at Airport Islands banding station. Models are ranked according to the difference from the best model based on Akaike's Information Criterion corrected for small sample size (AICc). K is the number of model parameters and w_i is the Akaike weight.

Model	K	AICc	ΔAICc	w_i
Julian	4	22.98	0	0.46
Julian + Water level	5	24.84	1.86	0.18
Julian + Flooded	5	25.17	2.19	0.15
null	2	25.61	2.63	0.12
Julian + Year	10	27.73	4.75	0.04
Year	8	28.03	5.04	0.04

Table S-4: Comparison of support for models of daily species richness at Airport Islands banding station. Models are ranked according to the difference from the best model based on Akaike's Information Criterion corrected for small sample size (AICc). K is the number of model parameters and w_i is the Akaike weight.

Model	K	AICc	ΔAICc	w_i
Julian + Water level	5	231.79	0	0.29
Julian + Year	10	232.54	0.74	0.20
Julian + Flooded	5	232.59	0.80	0.19
Julian	4	233.02	1.23	0.16
Year	8	234.25	2.46	0.08
null	2	234.40	2.61	0.08

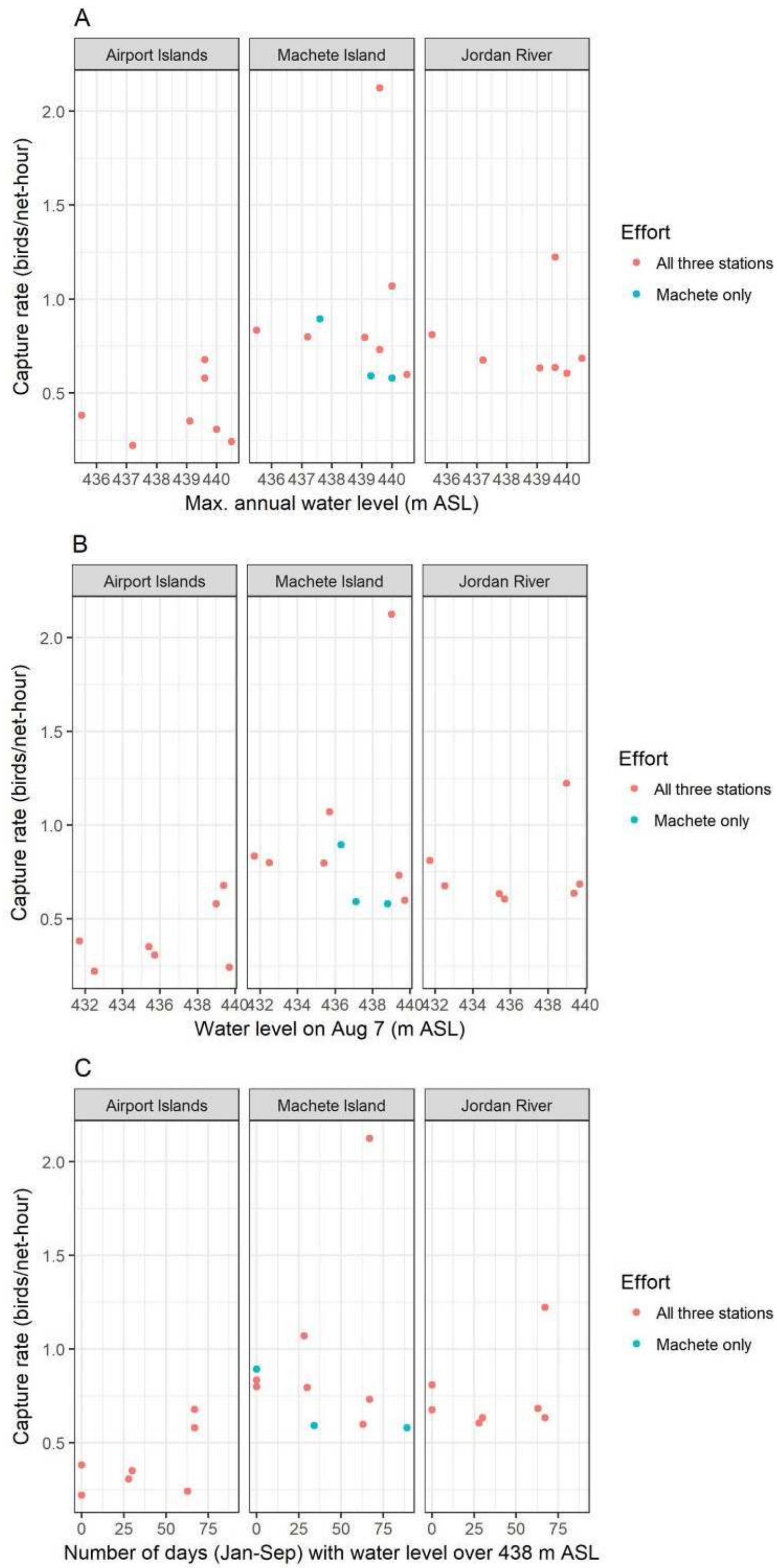


Figure S-1: Relationship between overall annual capture rate of newly-captured birds and three measures of annual reservoir operations at banding stations in the drawdown zone (Airport Islands, ~437 m ASL and Machete Island, ~ 439 m ASL) and control site outside of the drawdown zone (Jordan River, ~475 m ASL).

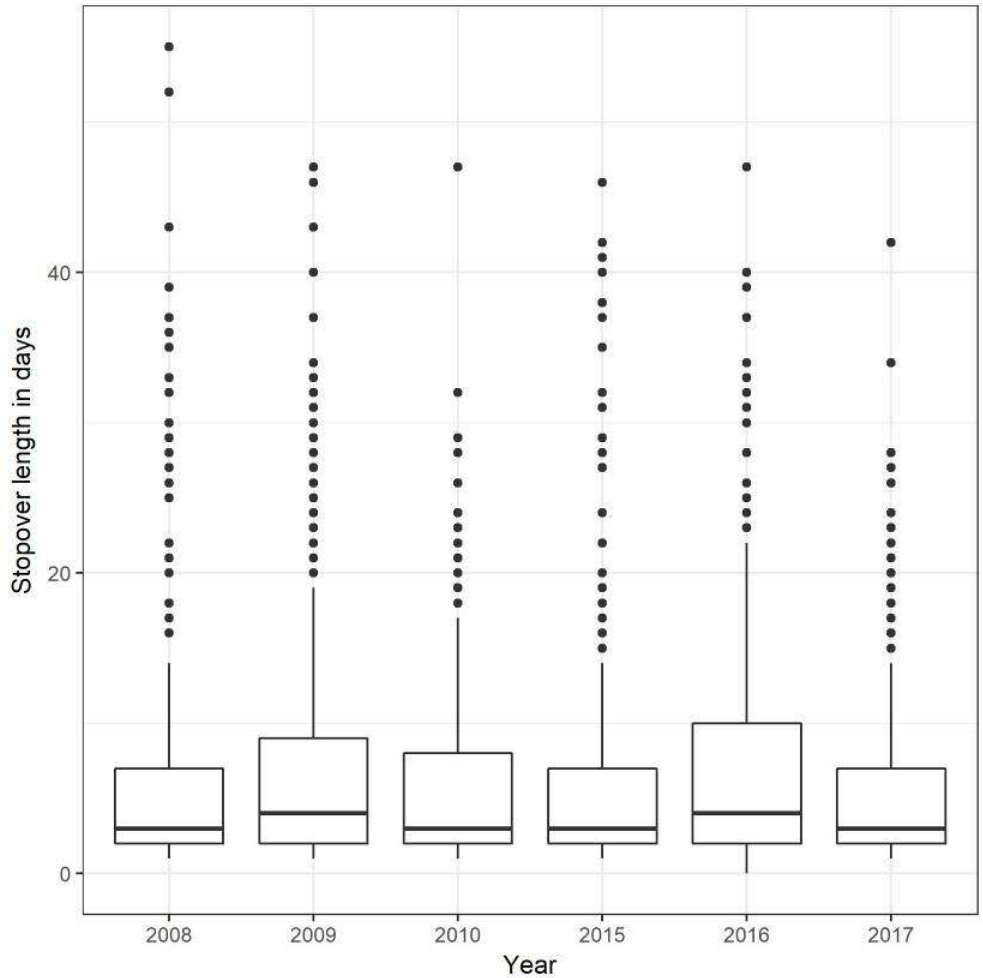


Figure S-2: Variation in stopover length among years at Machete Island banding station (all species pooled together, only years with daily monitoring included).

Appendix T. Assessment of the effects of reservoir operations on neotropical migrant abundance and species richness using permanent plot data.

Introduction: This analysis was conducted to assess the effect of reservoir water levels on presence of neotropical migrants on permanent plots.

Methods: Prior to analysis, all permanent plots were reclassified based on vegetation data collected in 2011 (habitat/vegetation data and in-field water depth observations). The following corrections to the original permanent plot classification were made:

1. Elevation band was adjusted for three plots at Montana Bay. Although these plots are located in the 436 m elevation band (based on digital elevation models), they are situated on a floating peat island and remain afloat even during full pool water levels. Therefore, they were reclassified into the 440 m elevation band.
2. Habitat strata for all permanent plots were adjusted based on collected habitat data, as follows:
    - Forest: plots with ≥ 5% tree cover (> 5 m high)
    - Shrub: plots with ≥ 5% shrub cover and < 5% tree cover
    - Grassland: plots with ≥ 10% grass/herbaceous cover and < 5% shrub cover
    - Unvegetated: plots with < 10% grass/herbaceous cover
3. Plots from the wetland stratum were reclassified into forest, shrub, grassland, and unvegetated strata. Due to heterogeneity of the wetland stratum (plots with herbaceous vegetation only, as well as plots with shrub and/or trees) and the fact that the whole drawdown zone is basically a large seasonally flooded wetland, the difference between a plot from the wetland stratum and a flooded grassland or shrub plot was not always apparent. Therefore, all permanent plots were classified into strata based only on vertical habitat structure.

Stratification of permanent plots is provided in Appendix C.

The effect of flooding was expressed by the relative water depth on plot on the day of survey. Water depth was calculated by subtracting the elevation of a plot from the reservoir water level on the day of survey. All calculated water depth values were cross-compared with water depth values recorded in the field. For these analyses, *a priori* maximum and minimum water depths were set to be ±4 meters and therefore surveys with calculated water depth greater than 4 m were given a water depth value of 4 m and surveys with water depth less than -4 m were given a water depth value of -4 m. Due to elevational stratification of habitat in the drawdown zone, 4 m is roughly the highest water depth that can be recorded on shrub or forest plots (areas above 436 m ASL). Habitat positioned lower in the drawdown zone can be inundated by deeper water but because of their lower vertical vegetation structure (grassland or unvegetated), these habitats become completely unavailable to migrants with water depth much lower than 4 m. Negative values of water depth represent that the plot was not inundated. We opted to use negative values, rather than adjust them to zero, because we believe that they provide some additional information without biasing the analysis. The utilization of monitoring plots can be influenced by the presence of water in close proximity of the plots (either just before the plot is inundated or right after the water retracts). Moreover, the inclusion of negative values helps buffer against potential imprecisions in either reservoir or plot elevation values.

Dataset: Dataset #9 was used for this analysis. In total, data from 2,788 surveys conducted in 2011 to 2014 (2011: n=582, 2012: n=773, 2013: n=771, 2014: n=662) were used. In total, 3,639 neotropical migrants of 49 species were recorded on plot.

There were 314 surveys when all migrant habitat was flooded (no habitat available); this subset was extracted from Dataset#9 and analyzes separately. The remaining subset containing 2,473 surveys were explored in more detail described below.

To assess the effect of water depth on plot, the dataset was further subdivided to analyze each habitat strata separately. Unvegetated plots (7 plots, 80 surveys) were excluded (no migrants presence) and only grassland plots (28 plots, 752 surveys), shrub plots (23 plots, 701 surveys) and forest plots (29 plots, 940 surveys) were further analyzed.

Analysis: To model the effect of water depth on the probability of the presence of a migrant songbird on a plot, binomial generalized linear mixed-effects models (GLMM) were used with the random effect 'plot ID'. The glmer function from the 'lme4' package for R (Bates et al. 2015) was used to run the models.

Three temporal variables were controlled for that it was suspected would influence neotropical migrant presence on plots:

(1) time of day when survey was initiated,
(2) time of year when survey was conducted (Julian date), and
(3) Year.

The latter variable was included to account for annual differences in migrant abundance and reservoir operations.

First, using univariate models and the pooled dataset from grassland, forest, and shrub plots (79 plots, n=2,393), the relationships between presence of migrants on plot and three temporal covariates were confirmed.

Plots from each stratum were analyzed separately because relationships were expected to differ among strata (due to different vertical vegetation structure and different use by migrants). Controlling for time after sunrise, time of year (Julian date), and year, the probability of the presence of a songbird on plot was modelled as a function of water depth on plot, with 'plot ID' as a random effect. Estimates from all the models are presented on a logit scale and likelihood-based confidence intervals were calculated using MASS package in R (Venables and Ripley 2002). R package visreg (Breheny and Burchett 2017) was used to transform and visualize fitted relationship on the original scale.

Results:

On plots that had all vegetation/habitat flooded (n=315), no birds were detected.

Neotropical migrants were never detected on an unvegetated plot during any of the surveys (n=80).

Pooling data from grassland, shrub, and forest plots (79 plots, n=2,393), the probability of the presence of a neotropical migrant on plot decreased with time after sunrise (GLMM (log odds) estimate (95% CI) = -2.07 (-3.27, -0.88)) and time of year (GLMM estimate (Log odds) = -0.02 (-0.02, -0.01) and varied among years.

On grassland plots (n=28), controlling for time after sunrise, time of year, and year, the probability of presence of a neotropical migrant on plot decreased with increasing water depth (n = 752; GLMM (Log odds) estimate (95% CI) = -0.61 (-0.80, -0.43); Figure 9). The random effect (plot id) variance was 0.82 with a standard deviation of 0.91.

On shrub plots (n=23), controlling for the three temporal variables, the presence of a migrant on plot was also negatively affected by increasing water depth on plot (n=701; GLMM (Log odds) estimate (95% CI) = -0.41 (-0.58, -0.25); Figure 10). Random effect (plot id) variance was 0.72 with a standard deviation of 0.85.

For forest plots (n=29), increasing water depth on plot tended to increase the presence of a migrant on plot, however this effect was not statistically significant (n = 940; GLMM (Log odds) estimate (95% CI) = 0.09 (-0.05, 0.23); Figure T-1). Random effect (plot id) variance was 0.43 with a standard deviation of 0.65.

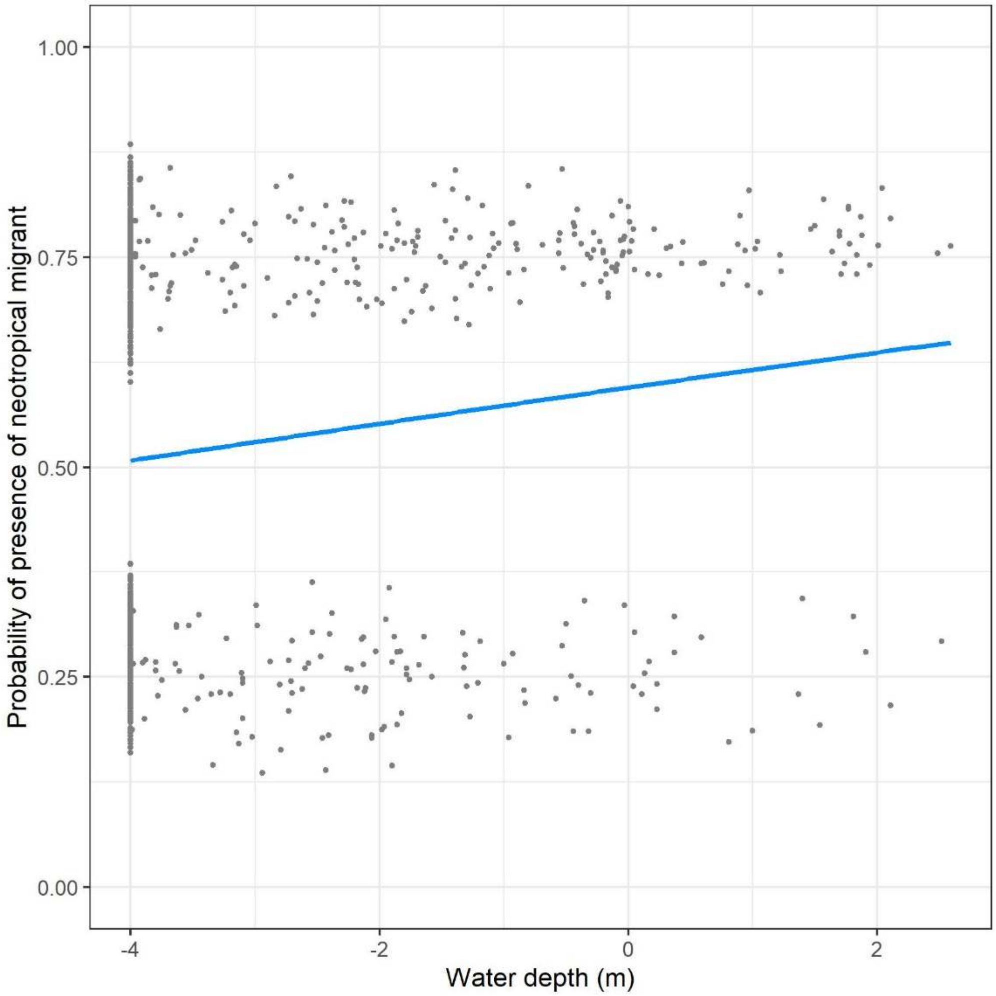


Figure T-1: Probability of presence of neotropical migrant on a forest plot based on water depth on plot. The blue line = model prediction (after controlling for time after sunrise, Julian date, and year). Partial residuals are plotted in gray.

Appendix U. Assessment of the effectiveness of the revegetation treatments in improving use of the treated habitat by fall neotropical migrants.

Introduction: These analyses were conducted to assess the effectiveness of revegetation treatments with cottonwood stakes in improving use of the treated habitat in the drawdown zone by fall neotropical migrants.

Dataset: Dataset #10 was used to assess the effectiveness of cottonwood revegetation projects in the drawdown zone. Fourteen treatment plots (planted with cottonwood stakes) and nine control plots (untreated area located in similar habitat) were monitored for five years (2011 to 2014 and 2016). To compare the neotropical migrant abundance and species richness between treatment and control plots, data from 919 surveys was used during which 663 neotropical migrant songbirds of 24 species were recorded on plot.

To look for any changes in abundance and species richness of migrants on treatment plots over time, a subset of dataset #10 was analyzed that included only data from weeks that were surveyed in all five years (subset #10A). This dataset contained 689 plot surveys during which 441 migrant songbirds of 20 species were recorded on plot.

Analysis: The first two analyses contrasted the responses (bird abundance, species richness) between treatment and control plots. The number of surveys of each plot varied among years (7 to 9 surveys per year) but was the same for all plots within the year. From these data, the cumulative number of birds/species detected on plot was calculated for each year (5 years X 23 plots = 115 data points for each analysis). For both analyses we used a generalized linear model (GLM), with strata (treatment vs. control) as a main effect and 'Treatment Site' included as a covariate to account for differences between treatment sites (both in terms of variation in migrant abundance among sites and variation in treatment success among sites). Initial models used a Poisson distribution but for the analysis of annual counts, overdispersion was detected (estimator = 4.26), so a quasi-Poisson GLM model was used instead (Zeileis et al. 2008).

Following, we assessed whether the abundance and species richness of migrants on treatment plots changed over the years of monitoring. Dataset #10A was used for these analyses and the cumulative number of birds/species detected on plot was calculated for each year (5 years X 4 treatment plots at each site = 20 data points for each site). Due to large variation in treatment success among treatment sites, and *a priori* reasons to suspect that the response of migrants might differ among sites, each site was analyzed separately. The analysis was conducted using GLM models with a quasi-Poisson distribution to model variation in migrant abundance among years and GLM models with a Poisson distribution to model variation in species richness among years.

Estimates from all the models are presented on log scale. Likelihood based 95% confidence intervals were calculated using the MASS package in R (Venables and Ripley 2002) and R package visreg (Breheny and Burchett 2017) was used to transform and visualize the fitted relationship on the original scale.

Results: Pooling data from all years and controlling for treatment area, the mean annual cumulative abundance of migrants per plot was significantly higher on treatment plots than on control plots (n = 115; estimate (Log) (95% CI) = 0.540 (0.175, 0.927); Figure U-1); however, this effect was not evenly observed among sites. Among different planted areas, the only significant difference in migrant abundance between treatment and control plots was on plots in the McKay Creek area (n= 35; treatment plots had higher abundance; estimate (Log) = 0.744 (0.226, 1.308).

There was no significant difference in the mean annual cumulative species richness per plot between treatment and control plots (n = 115; estimate (Log) = 0.249 (-0.015, 0.519); Figure U-2). Among different planted areas, the only significant difference in migrant species richness between treatment and control plots was at McKay Creek (n = 35; treatment plots had higher abundance; estimate (Log) = 0.491 (0.054, 0.953).

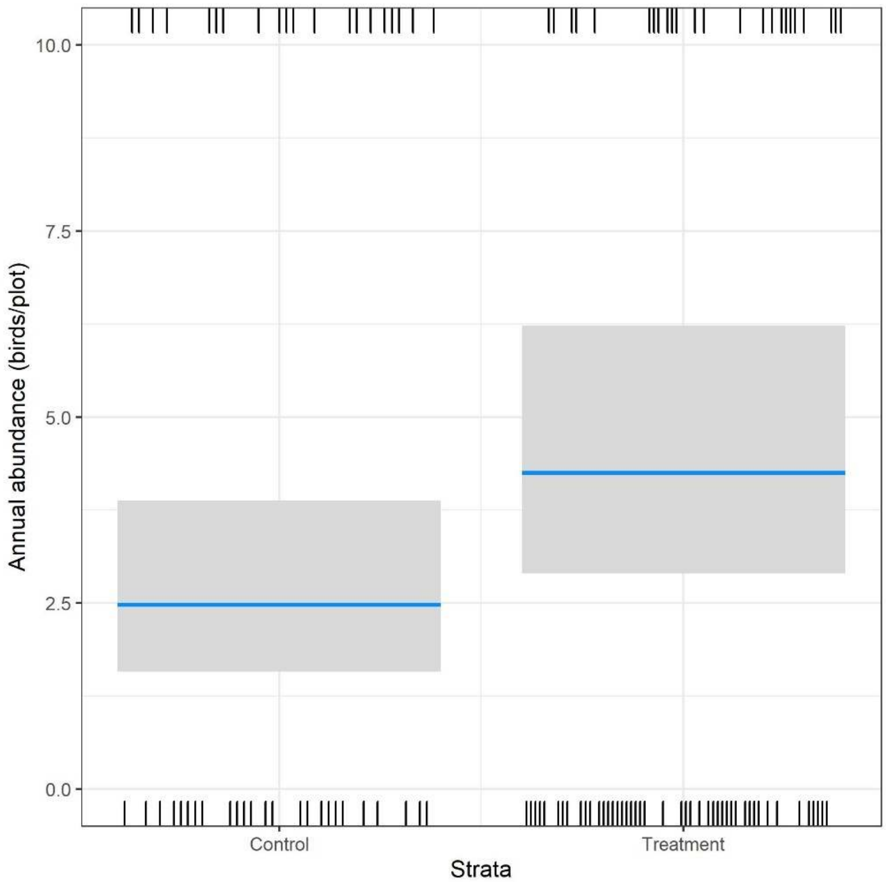


Figure U-1: Difference in cumulative annual abundance of neotropical migrants on treatment plots compared to control plots. Model prediction (blue line, controlling for treatment area), 95% confidence interval (gray area).

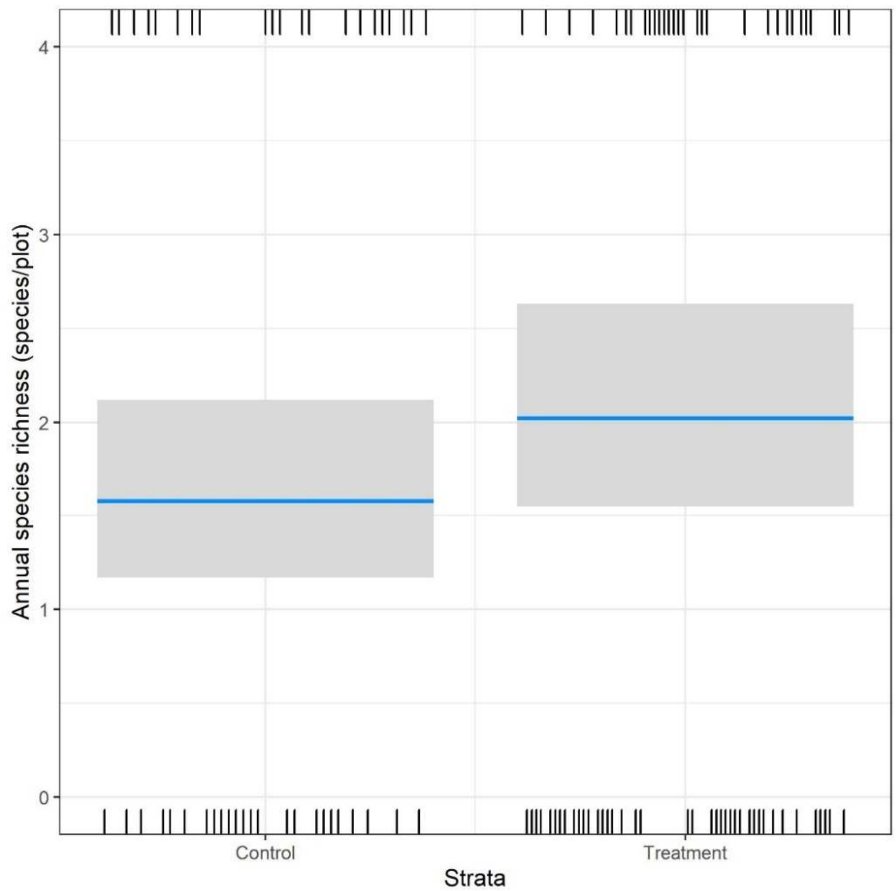


Figure U-2: Difference in cumulative annual species richness of neotropical migrants on treatment plots compared to control plots. Model prediction (blue line, controlling for treatment area), 95% confidence interval (gray area).

The changes in abundance of migrants over time varied among treatment sites (Figure U-3). At the 12 Mile area, the cumulative annual abundance of migrants on treatment plots decreased compared to the first year of monitoring (n = 20; Log estimate (2016) = -1.482 (-2.192, -0.863); Figure U-5). Conversely, at McKay Creek area, the cumulative annual abundance of migrants on treatment plots increased over time (n = 20; Log estimate (2016) = 1.682 (0.698, 2.946); Figure U-6). At 9 Mile area, there was not a significant change in abundance per treatment plot over time (n = 20; Log estimate (2016) = 1.335 (-0.222, 3.530); Figure U-7).

Similarly, the changes in species richness over time varied among treatment areas (Figure U-4). Species richness increased at 9 Mile area (n = 20; Log estimate (2016) = 1.204 (0.020, 2.699); Figure U-8), and decreased at 12 Mile area (n = 20; Log estimate (2016) = -0.847 (-1.680, -0.097); Figure U-9). At McKay Creek area, the change in species richness over time was not significant (n = 20; Log estimate (2016) = 0.847 (-0.066, 1.885); Figure U-10).

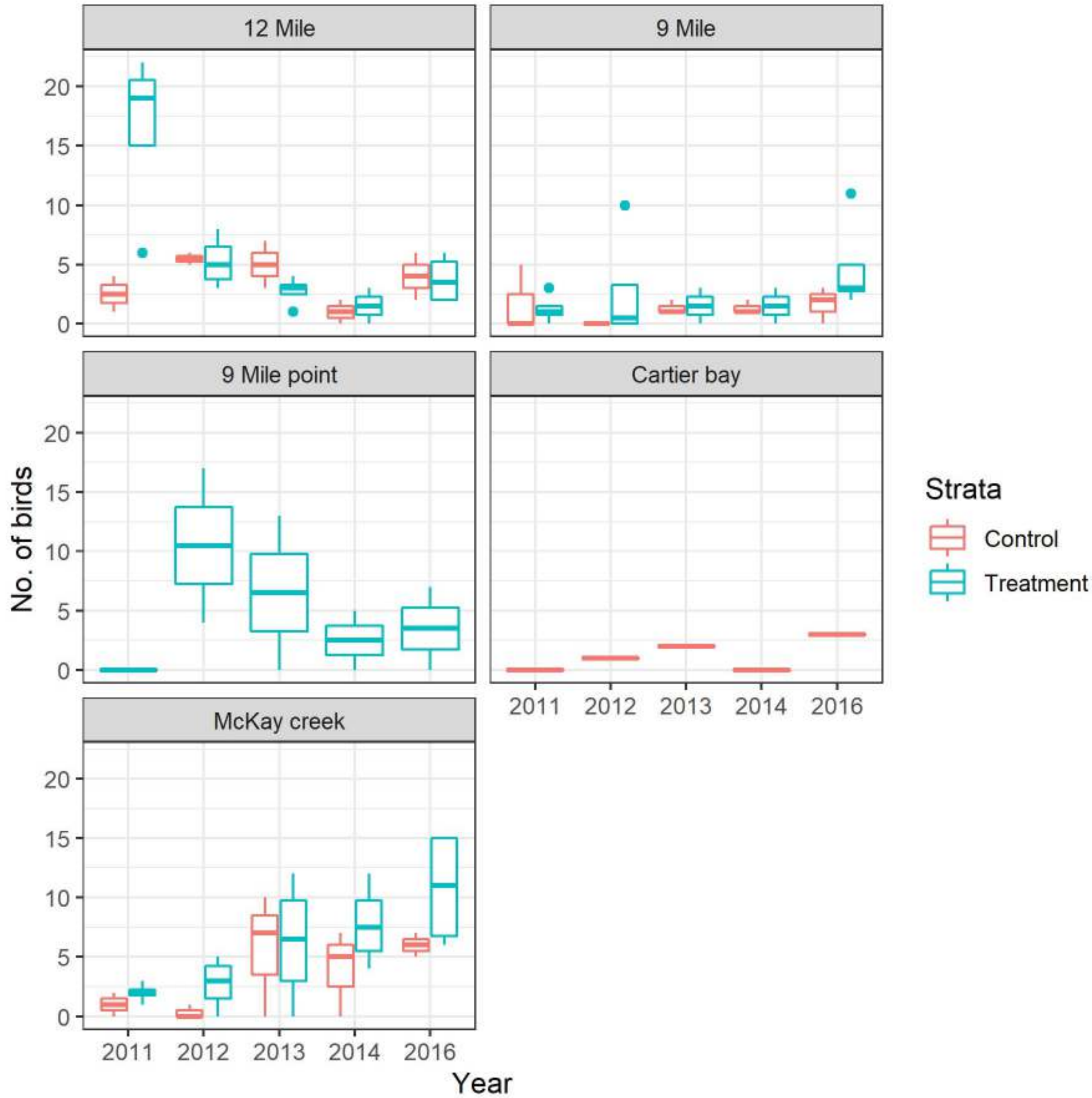


Figure U-3: **Mean cumulative annual abundance per plot of fall neotropical migrants on effectiveness monitoring plots in different planted areas.**

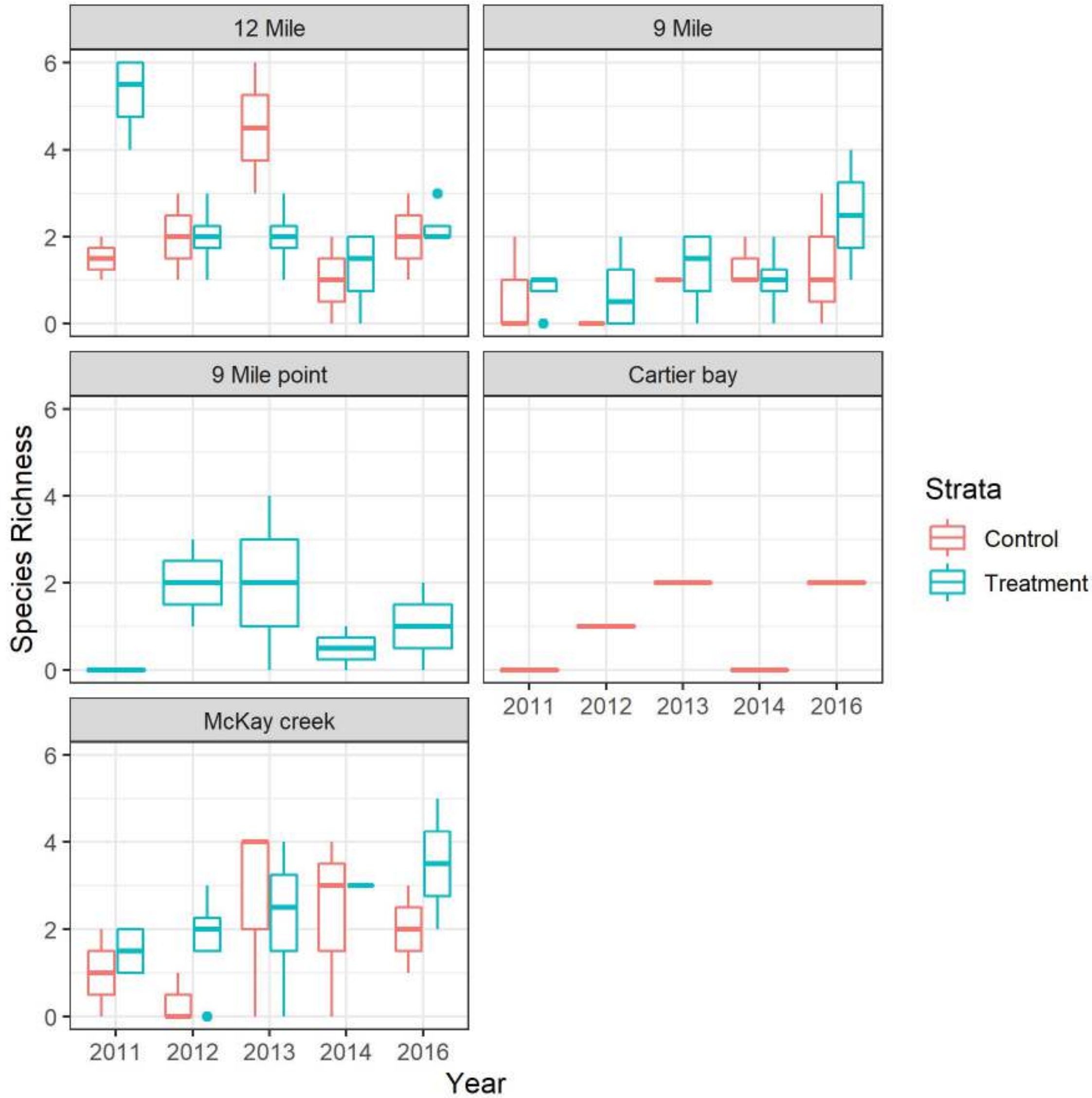


Figure U-4: **Mean cumulative annual species richness per plot of fall neotropical migrants on effectiveness monitoring plots in different planted areas.**

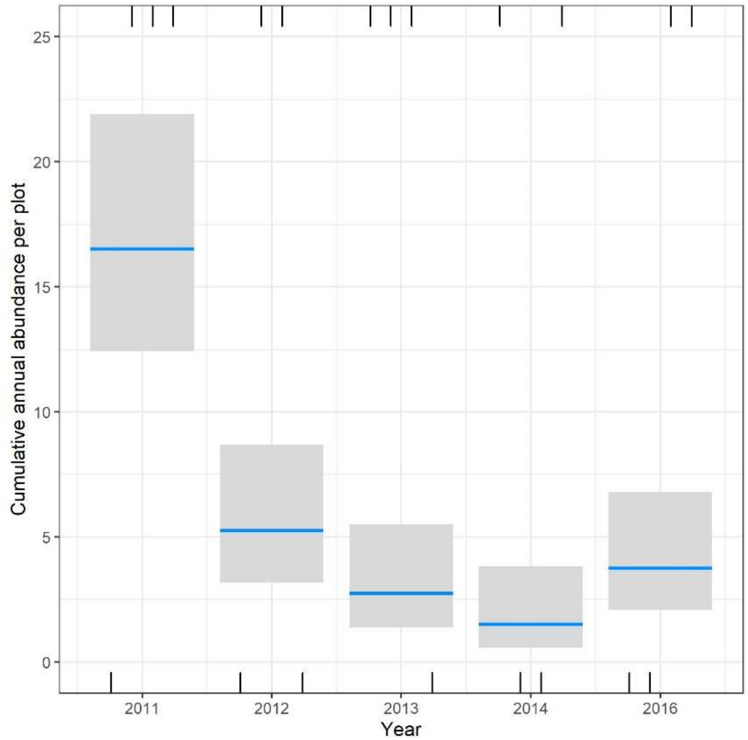


Figure U-5: Variation in cumulative annual abundance of neotropical migrants on treatment plots at 12 Mile area in 2011 to 2016. Model prediction (blue line), 95% confidence intervals (gray area).

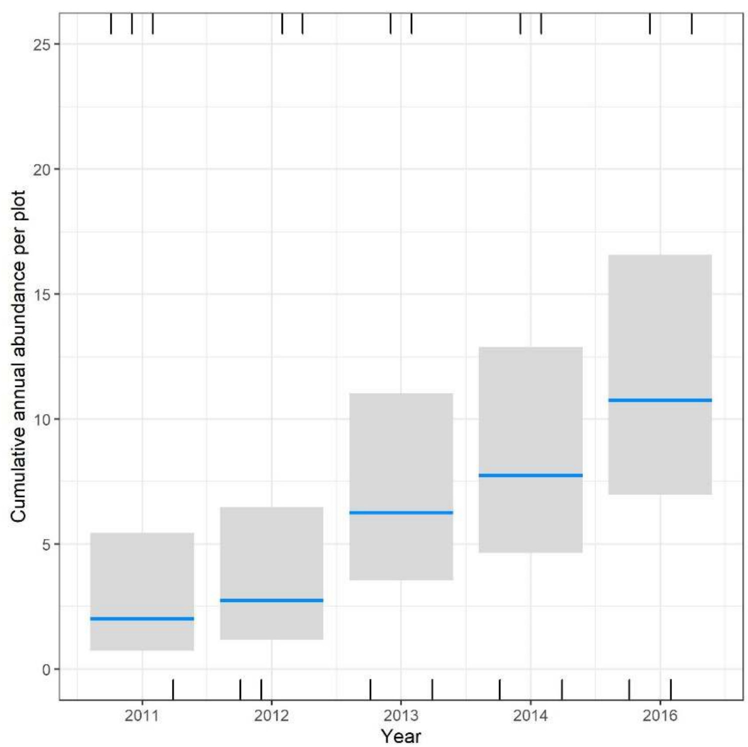


Figure U-6: Variation in cumulative annual abundance of neotropical migrants on treatment plots at McKay Creek area in 2011 to 2016. Model prediction (blue line), 95% confidence intervals (gray area).

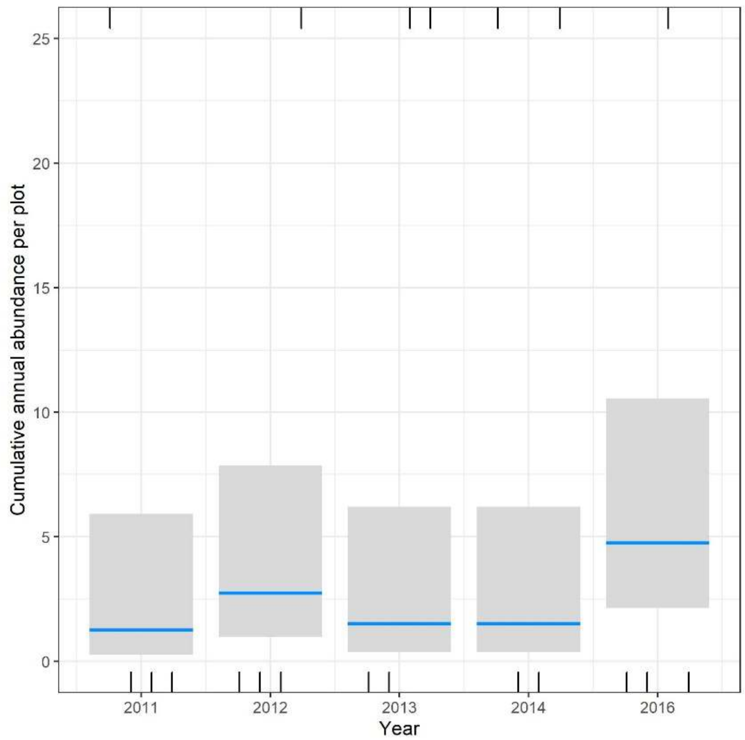


Figure U-7: Variation in cumulative annual abundance of neotropical migrants on treatment plots at 9 Mile area in 2011 to 2016. Model prediction (blue line), 95% confidence intervals (gray area).

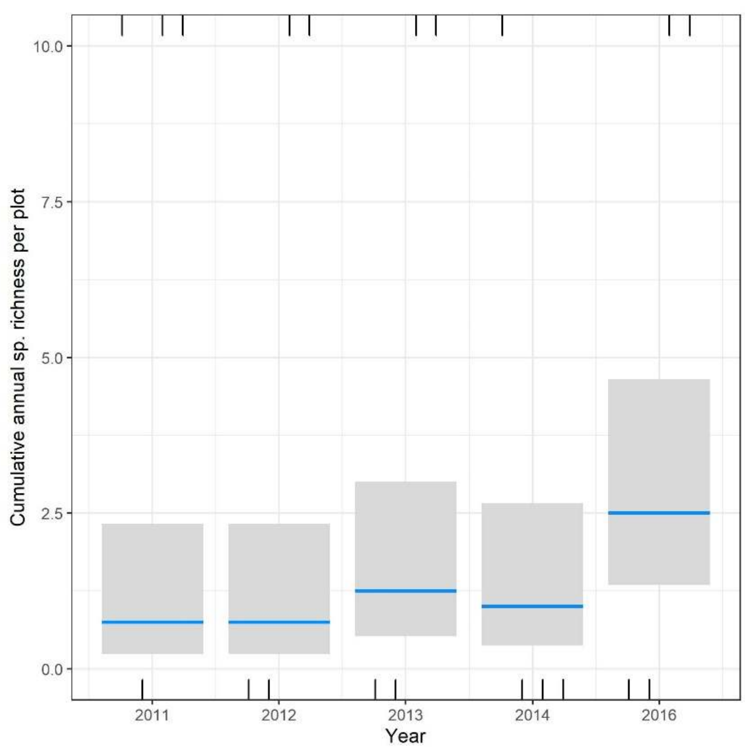


Figure U-8: Variation in cumulative annual species richness of neotropical migrants on treatment plots at 9 Mile area in 2011 to 2016. Model prediction (blue line), 95% confidence intervals (gray area).

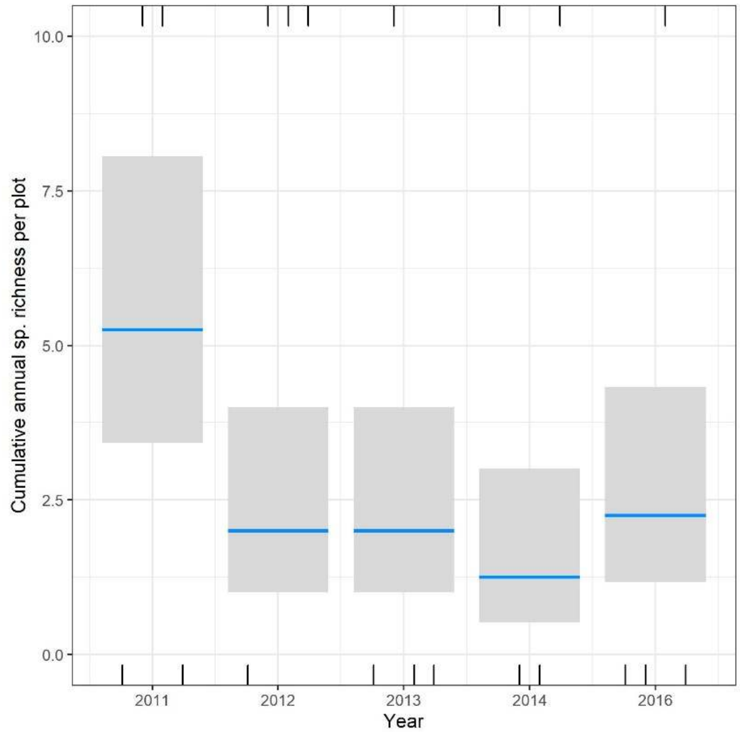


Figure U-9: Variation in cumulative annual species richness of neotropical migrants on treatment plots at 12 Mile area in 2011 to 2016. Model prediction (blue line), 95% confidence intervals (gray area).

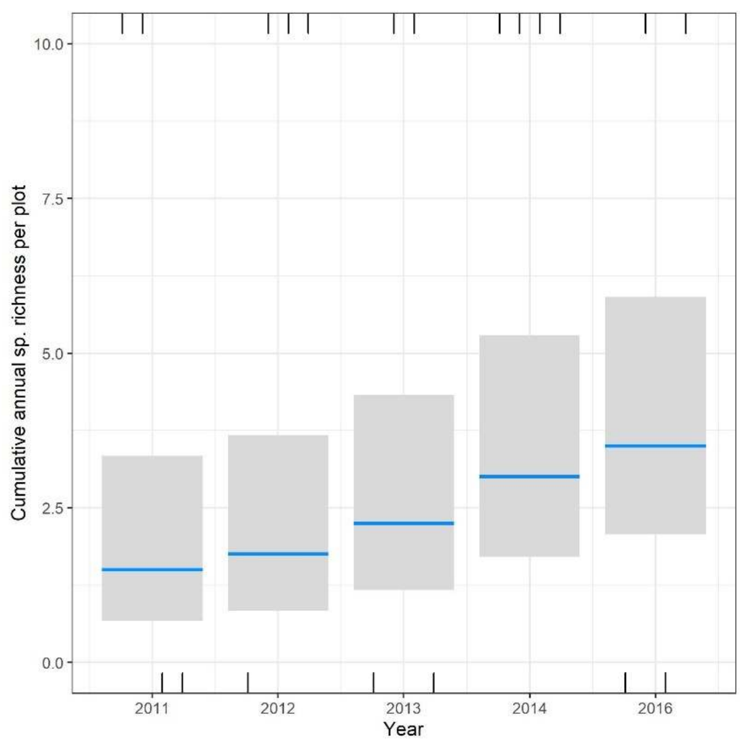


Figure U-10: Variation in cumulative annual species richness of neotropical migrants on treatment plots at McKay Creek area in 2011 to 2016. Model prediction (blue line), 95% confidence intervals (gray area).

Appendix V. Availability of habitat in the drawdown zone of Revelstoke Reach by habitat type.

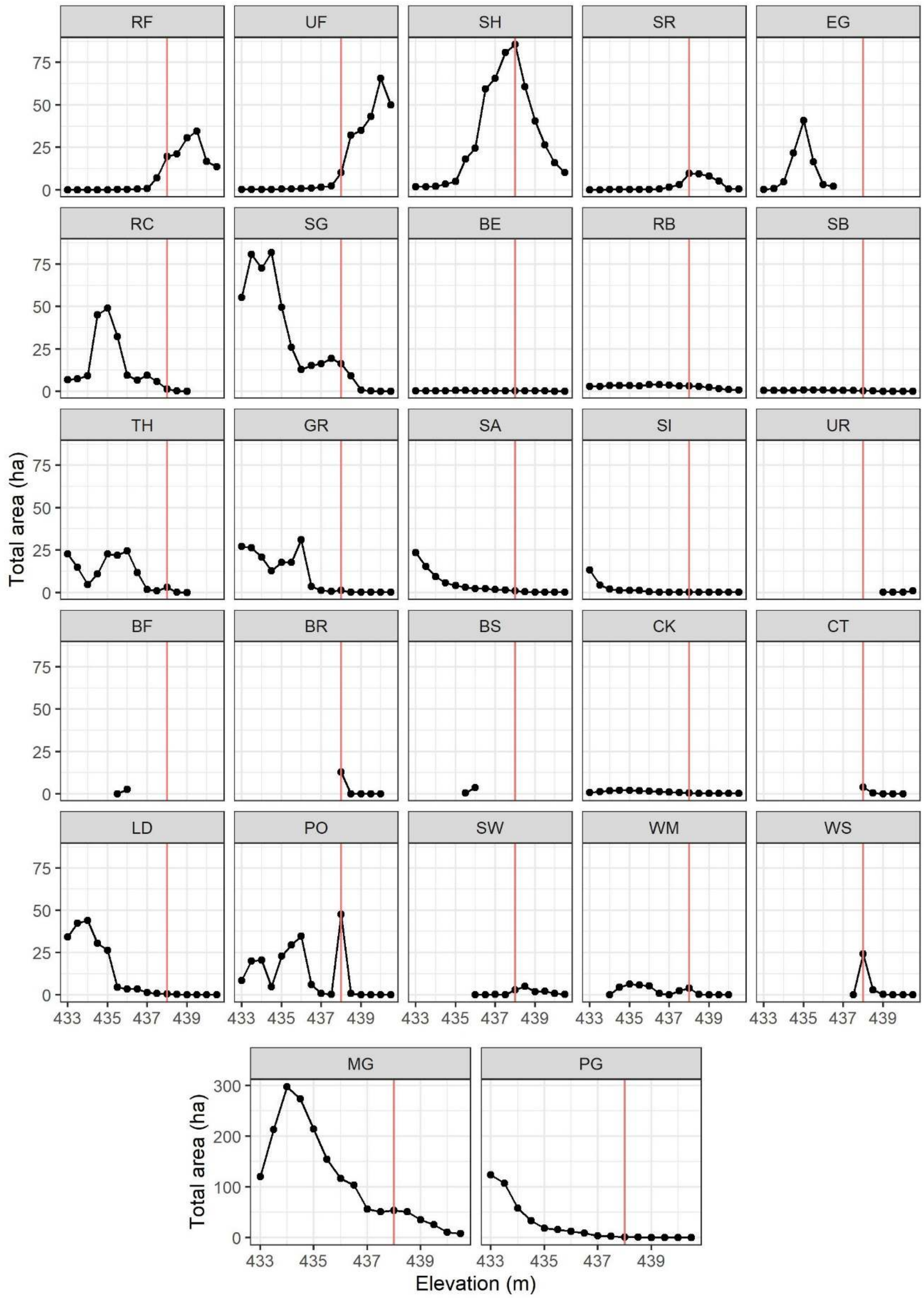


Figure V-1: The area of the drawdown zone covered by each habitat type in each 0.5 m elevation band in Revelstoke Reach. Red vertical line = 438 m ASL. Habitat type codes are provided in Appendix D.

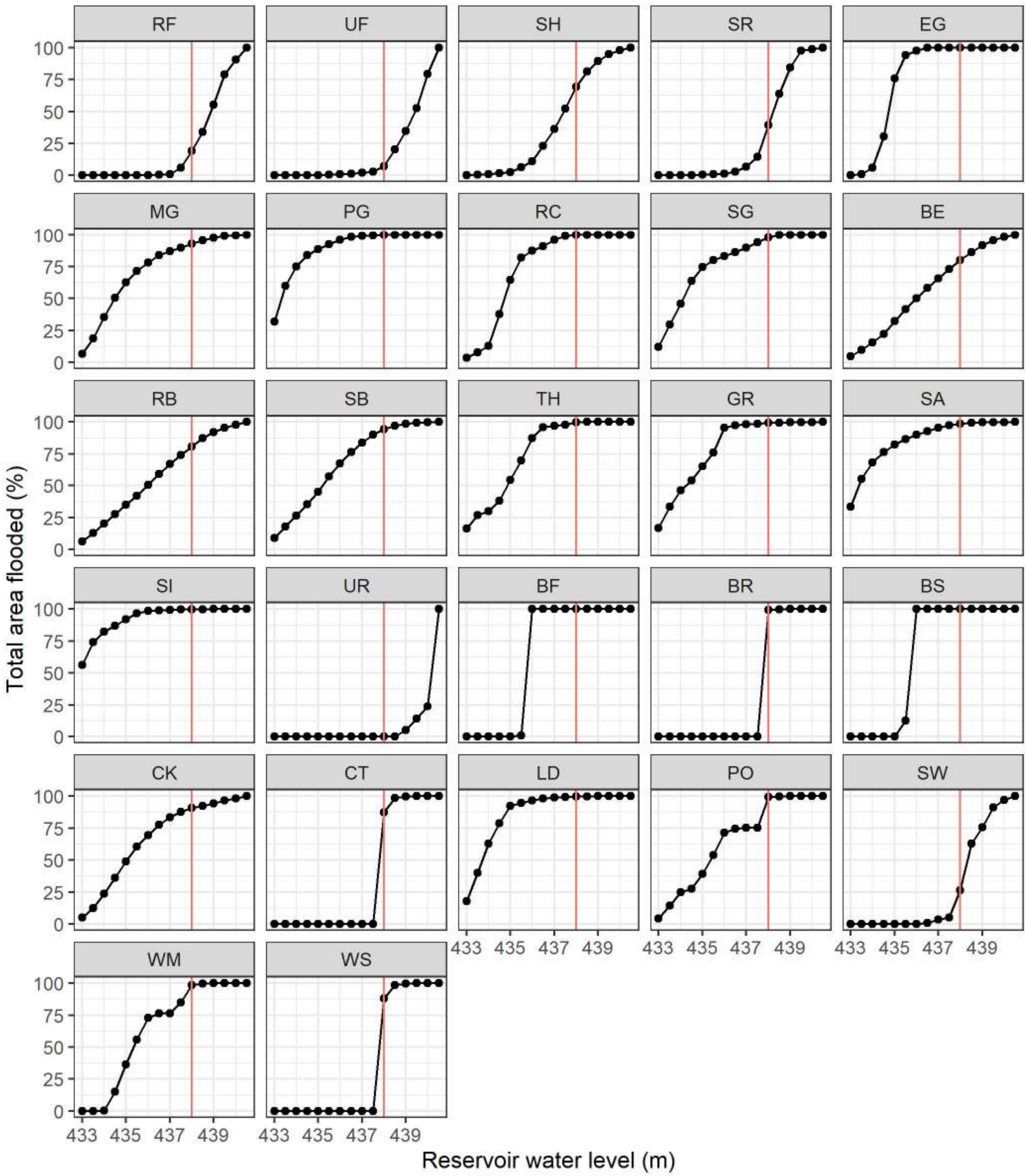


Figure V-2: Availability of each habitat type in Revelstoke Reach under different reservoir levels. Red vertical line = 438 m ASL. Habitat type codes are provided in Appendix D.

Appendix W. Assessment of the effectiveness of the revegetation treatments in improving use of the treated habitat by spring neotropical migrants.

Introduction: These analyses were conducted to assess the effectiveness of revegetation treatments with cottonwood stakes in improving use of the treated habitat in the drawdown zone by spring neotropical migrants.

Dataset: Dataset #11 was used which contained data collected on 14 treatment plots (planted with cottonwood stakes) and eight control plots (untreated area located in similar habitat) over a period of six years for the 12 Mile area (2010 to 2014 and 2016), and for a period of five years (2011 to 2014 and 2016) for the other treatment sites. In order to standardize survey effort across years, only surveys in weeks that were monitored in all years of monitoring (for each site) were included in this dataset (12 Mile area plots had five surveys per year, 9 Mile area plots four surveys per year, McKay Creek area had five surveys per year, and 9 Mile point had four surveys per year). However, for McKay Creek area, data for one missing survey in 2016 were generated (as a median of values from other treatment plots in that area) to preserve sample size and prevent further trimming of the dataset. In total, 578 surveys were analyzed (12 Mile area = 180 surveys, 9 Mile area = 148 surveys, 9 Mile point area = 40 surveys, and McKay Creek area = 210 surveys) which included records of 336 neotropical migrants of 22 species.

Analysis: For analysis, the cumulative number of birds and species detected on plot was calculated for each plot each year.

To compare bird abundance between treatment and control plots, a generalized linear model (GLM) was used, with the cumulative annual number of birds on plot per year as the dependent variable, and strata (treatment vs. control) as a main effect. The term ‘Treatment Site’ was included as a covariate to account for differences between treatment sites (migrant abundance and treatment success). Analysis began with a model with a Poisson distribution but large overdispersion (estimator = 11.0) was detected so a quasi-Poisson GLM model (Zeileis et al. 2008) was used instead.

To test the difference in species richness between treatment and control plots, a GLM model with Poisson distribution was used. Cumulative annual species richness was the dependent variable, strata was a main effect, and ‘Treatment Site’ was a covariate.

A longitudinal analysis was also conducted to assess whether there was a change in abundance and species richness of migrants on treatment plots over the years of monitoring. Due to large variation in treatment success among sites, and *a priori* reasons to suspect that the response of migrants might differ among sites, each site was analyzed separately. GLM models with a quasi-Poisson distribution were used to model variation in migrant abundance among years and GLM models with a Poisson distribution were used to model variation in species richness among years. Estimates from all the models are presented on a log scale. Likelihood based 95% confidence intervals were calculated using MASS package (Venables and Ripley 2002) and R package visreg (Breheny and Burchett 2017) was used to transform and visualize fitted relationship on the original scale.

Results: Controlling for treatment site, the mean annual cumulative abundance of migrants per plot did not significantly differ between treatment plots and control plots (n = 116; estimate (Log) (95% CI) = 0.189 (-0.577, 1.018); Figure W-1). This difference was not significant at any of the treated sites

The mean annual cumulative species richness per plot was higher on the treatment than on the control plots (n = 116; estimate (Log) = 0.402 (0.005, 0.822); Figure W-2). Among different planted areas, the only significant difference in annual migrant species richness between treatment and control plots was at 9 Mile area (n = 35; treatment plots had higher abundance; estimate (Log) = 0.965 (0.226, 1.820), and at McKay Creek area (n = 35; treatment plots had higher abundance; estimate (Log) = 1.447 (0.356, 2.902).

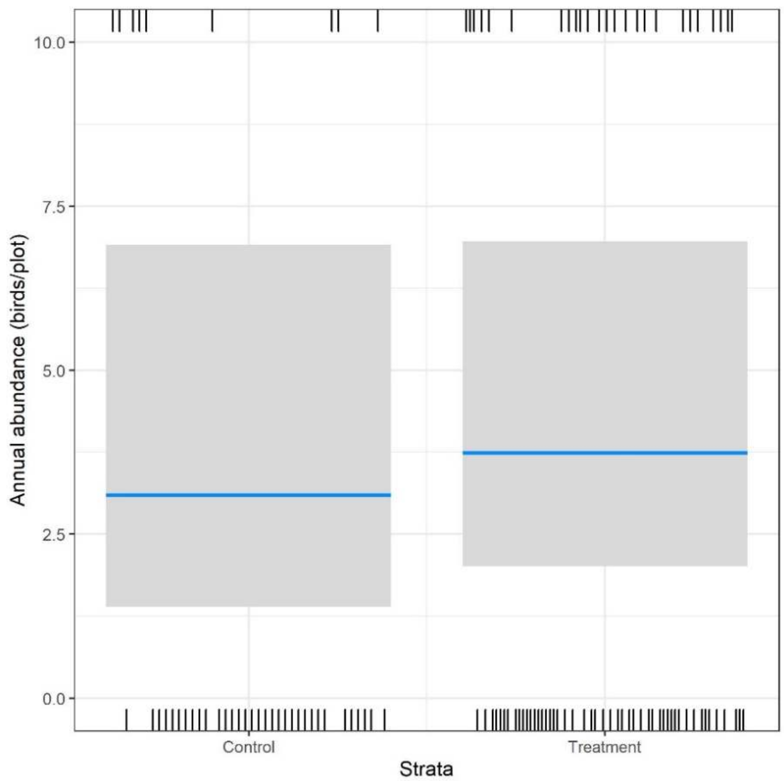


Figure W-1: Difference in cumulative annual abundance of neotropical migrants on treatment plots compared to control plots. Model prediction (blue line, controlling for treatment area), 95% confidence interval (gray area).

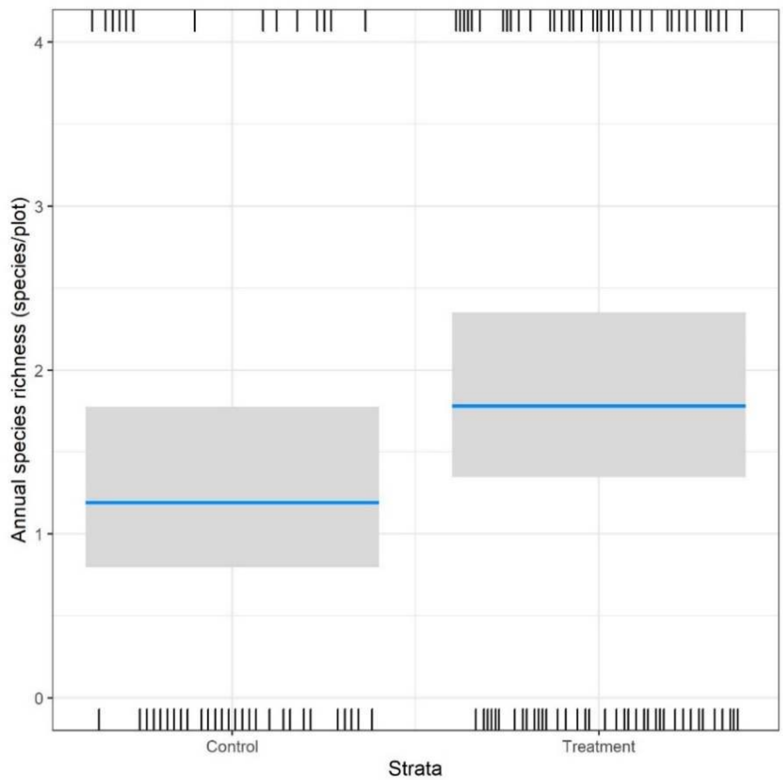


Figure W-2: Difference in cumulative annual species richness of neotropical migrants on treatment plots compared to control plots. Model prediction (blue line, controlling for treatment area), 95% confidence interval (gray area).

The changes in cumulative annual abundance of migrants varied among treatment and control sites over time (Figure W-3). At the 12 Mile area, the cumulative annual abundance of migrants on treatment plots decreased over time compared to the first year of monitoring (n = 24; Log estimate (2016) = -2.160 (-5.739, -0.266); Figure W-5). Similarly, at the 9 Mile area, the cumulative annual abundance on treatment plots decreased over time (n = 20; Log estimate (2016) = -2.639 (-9.765, -0.100); Figure W-6). However, the abundance of migrants at the McKay Creek area (n = 20) did not significantly change over time.

The changes in species richness of migrants varied among treatment and control sites (Figure W-4). Over time, species richness on plots at the 12 Mile area was relatively constant but there was a decrease in abundance in 2016, though not significant (n = 24; Log estimate (2016) = -1.253 (-3.157, 0.167); Figure W-7). The cumulative annual species richness on treatment plots at the 9 Mile area also decreased in 2016 (n = 20; Log estimate = -1.946 (-4.874, -0.220); Figure W-8). There was no significant trend in species richness over time at other treatment sites.

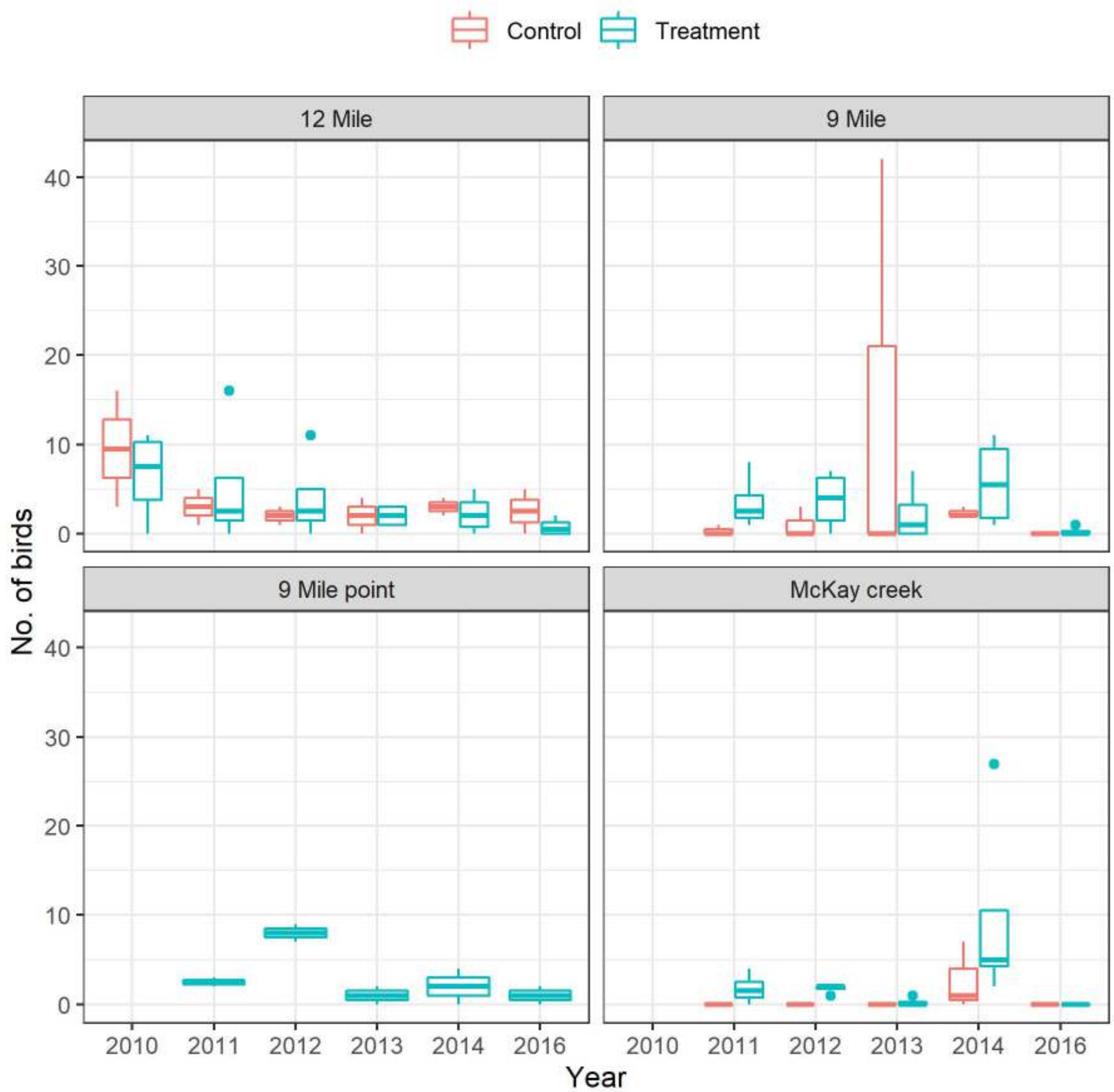


Figure W-3: **Mean cumulative annual abundance per plot of spring neotropical migrants on effectiveness monitoring plots in different planted areas**

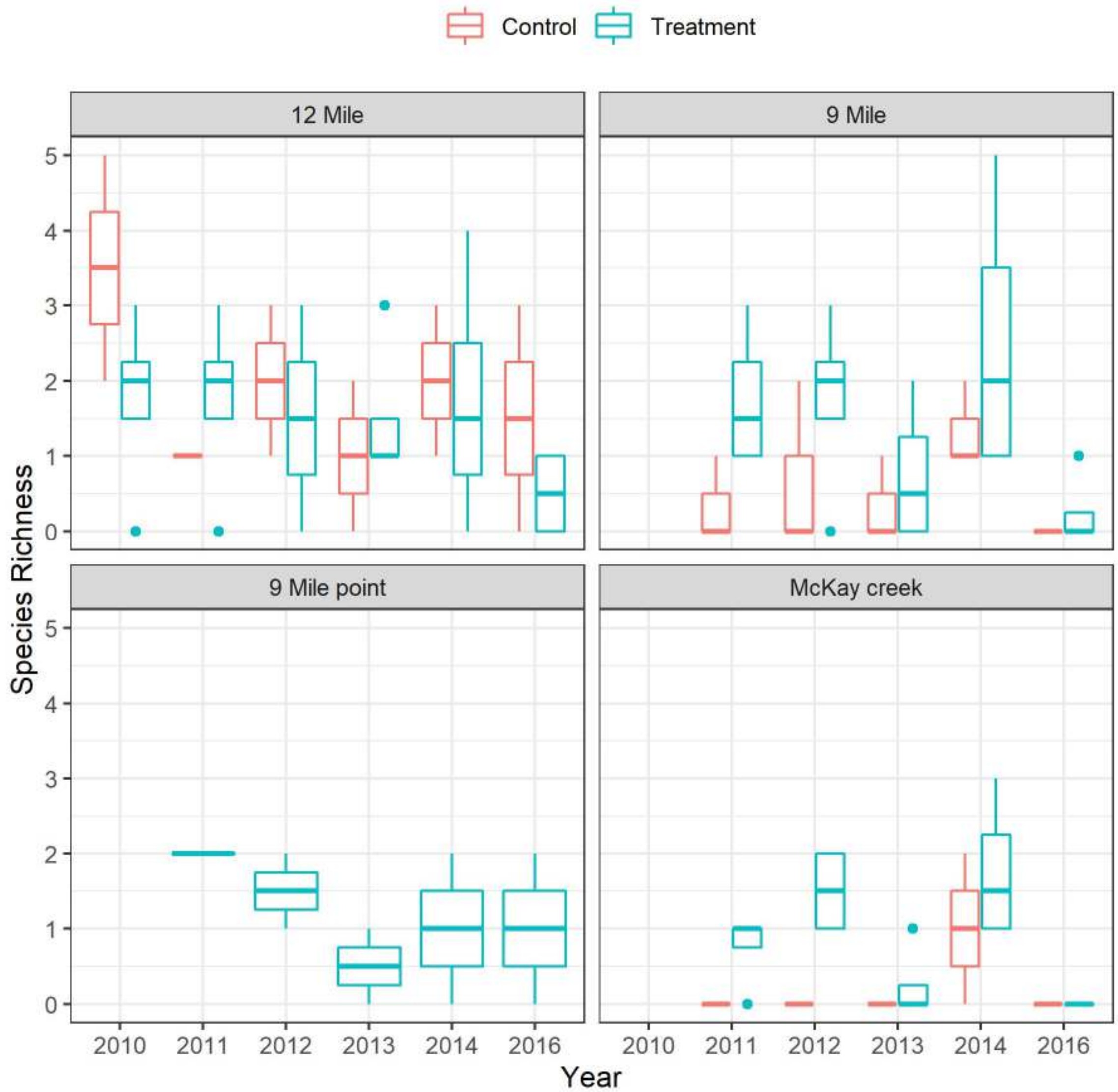


Figure W-4: **Mean cumulative species richness per plot of spring neotropical migrants on effectiveness monitoring plots in different planted areas**

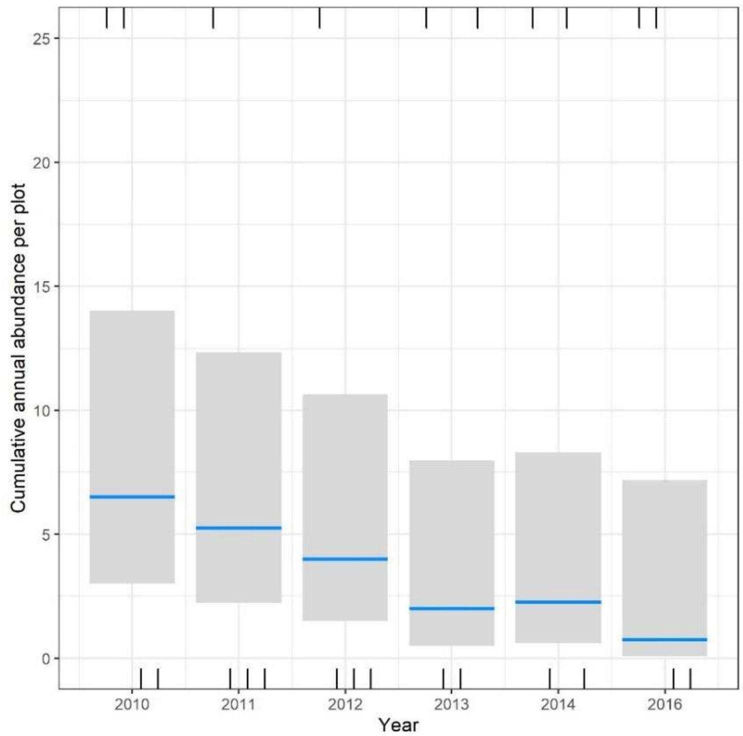


Figure W-5: Variation in cumulative annual abundance of neotropical migrants on treatment plots at 12 Mile area in 2010 to 2016. Model prediction (blue line), 95% confidence intervals (gray area).

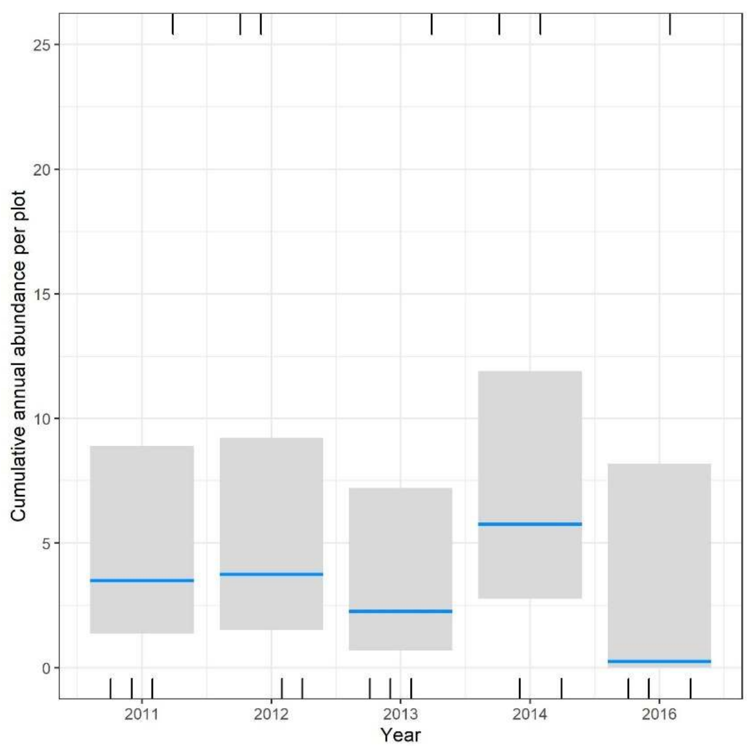


Figure W-6: Variation in cumulative annual abundance of neotropical migrants on treatment plots at 9 Mile area in 2011 to 2016. Model prediction (blue line), 95% confidence intervals (gray area).

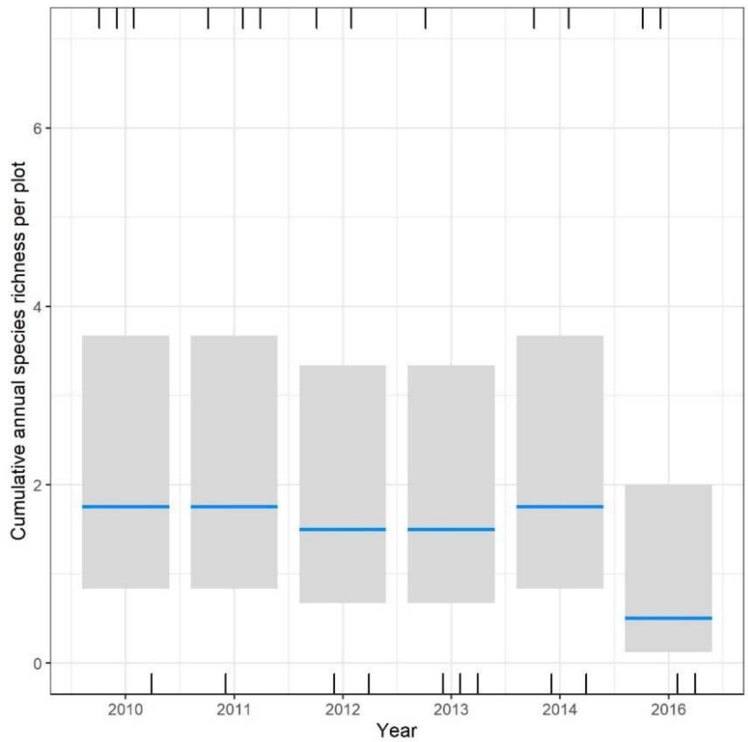


Figure W-7: Variation in cumulative annual species richness of neotropical migrants on treatment plots at 12 Mile area in 2010 to 2016. Model prediction (blue line), 95% confidence intervals (gray area).

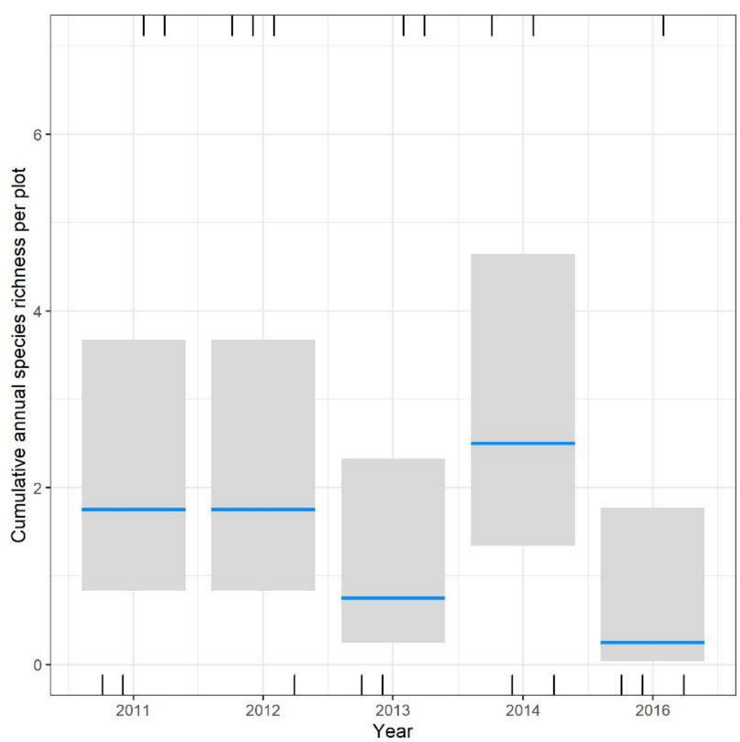


Figure W-8 Variation in cumulative annual species richness of neotropical migrants on treatment plots at 9 Mile area in 2011 to 2016. Model prediction (blue line), 95% confidence intervals (gray area).