Columbia River Project Water Use Plan

Kinbasket and Arrow Reservoirs Revegetation Management Plan

Arrow Lakes Reservoir: Wildlife Effectiveness Monitoring and Enhancement Area Identification for Lower and Mid-Arrow Lakes Reservoir

Implementation Year 7

Reference: CLBMON-11B1

Final Annual Report

Study Period: 2016

Okanagan Nation Alliance, Westbank, BC

and

LGL Limited environmental research associates
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KINBASKET AND ARROW LAKES RESERVOIRS

Monitoring Program No. CLBMON-11B1
Wildlife Effectiveness Monitoring and Enhancement Area Identification for Lower and Mid-Arrow Lakes Reservoir




Final Report 2016

Prepared for

BC Hydro

BC Hydro Generation

Water Licence Requirements
6911 Southpoint Drive
Burnaby, BC

Prepared by

Virgil C. Hawkes[1], M.Sc., R.P.Bio, Janean K. Sharkey[1], B.Sc., R.P.Bio., Nathan Hentze[1], M.Sc., Charlene Wood[1], M.Sc., Jeremy Gatten[1], B.Sc. and Autumn Solomon[2], B.Sc.

[1]LGL Limited environmental research associates

and

[2]Okanagan Nation Alliance

Technical Contact: Virgil C. Hawkes, M.Sc., R.P.Bio.
vhawkes@gl.com; 1.250.656.0127

ONA Contact: Lisa Wilson; 1.250.707.0095 x213

January 23, 2018

syilx Okanagan Nation Alliance

LGL LIMITED environmental research associates

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From left to right: Beaton Arm beaver ponds; Eastern Kingbird (*Tyrannus tyrannus*); western tiger swallowtail (*Papilio rutulus*); and sedge plug at Burton Creek © Virgil C. Hawkes, LGL Limited.

EXECUTIVE SUMMARY

CLBMON-11B1, initiated in 2009, is a long-term wildlife monitoring project to assess the efficacy of revegetation prescriptions (i.e., those implemented under CLBWORKS-2) in enhancing the suitability of habitats in the drawdown zone of Arrow Lakes Reservoir for wildlife, and to develop a minimum of three wildlife enhancement prescriptions that can be implemented in the drawdown zone to further improve habitat suitability (i.e., CLBWORKS-29B). Work for CLBMON-29B was completed in 2012 and updated in 2016 in a separate document. Between 2009 and 2016, work associated with CLBMON-11B1 focused on areas revegetated under CLBWORKS-2 between Shelter Bay and Edgewood.

There are three management questions (MQs) addressed by CLBMON-11B1: (1) Are the revegetation and the wildlife physical works projects effective in enhancing wildlife habitat in the drawdown zone? (2) If the revegetation and the wildlife physical works projects enhance wildlife habitat in the drawdown zone, to what extent does the revegetation project and the wildlife physical works projects increase the productivity of habitat in the drawdown zone for wildlife? (3) Are some methods or techniques more effective than others in enhancing wildlife habitat in the drawdown zone?

The revegetation prescriptions applied in the drawdown zone may affect prey populations (i.e., terrestrial and/or aerial arthropods) before they affect the predators of those arthropods (songbirds and bats). Thus, since 2013 we have sampled songbirds, arthropods, and bats as focal taxa. Prior to 2013, ungulates surveys were also conducted. Bats were incorporated into the sampling program in 2010 because of the known relationships between bats, wetland and riparian habitat, and arthropods, which are their primary food source. The direction and magnitude of changes in arthropod populations is being tracked over time and will serve as a metric to assess the efficacy of each revegetation prescription applied in the drawdown zone.

Four types of experimental sampling areas were classified within sites (collectively, “habitat types”). Three of these habitat types were established in terrestrial areas of the reservoir drawdown zone (i.e., at elevations below the normal operating maximum; ≤ 440.1 m ASL): “treatment”, “control”, and “drawdown zone”. Each treatment polygon delimited the area of the drawdown zone that was revegetated using one of seven revegetation prescriptions implemented under CLBWORKS-2. A control polygon was established adjacent to each treatment polygon, to serve as untreated (i.e., not revegetated) paired controls within the study sites that were revegetated. Drawdown zone sampling areas were similar to controls, but occurred in study sites without revegetation prescriptions. Sampling was also conducted in “reference” areas that were established upland of the reservoir (> 440.1 m ASL) to serve as non-drawdown zone controls. These are monitored to assess regional and natural variation in the taxa being studied.

We found two distinct groupings of both arthropod and songbird communities that represented the upland reference sampling areas and all drawdown zone sampling areas (treatment, control, and drawdown zone, collectively). Composition did not differ between control and treatment areas of the drawdown zone for any of the arthropod taxa identified, nor for songbird species. These results were consistent with prior monitoring years. Further, there was no apparent relationship between revegetation prescriptions and the biomass of arthropods or the relative

abundance of arthropods and songbirds. The results of work to date reveal some site species-specific patterns, but collectively, the results do not support an assessment of treatment effects. This could be related to the issues associated with experimental design, with sample size for certain taxa too small to permit pairwise comparisons of treatments and controls (e.g., birds), and a lack of pre-treatment data.

The variable administration and mixed success of the revegetation prescriptions are likely contributing to the lack of measureable treatment effects. Study of revegetation areas in the drawdown zone inherits experimental design challenges that are important to acknowledge. For example: i) treatment areas vary in the type of revegetation prescription applied, ii) inadequate replication of revegetation treatments iii) the size of treated areas are small, and iv) survival of the vegetation is both spatially and temporally variable, such that some treatment areas have largely failed since application (i.e., low plant survival).

Monitoring the use of the drawdown zone by bats resulted in the documentation of 12 species of bat occurring in mid- and lower Arrow Lakes Reservoir. Five of these species are of provincial/national conservation concern, including Townsend's Big-eared Bat, Western Small-footed Myotis, Northern Myotis, Fringed Myotis, and Little Brown Myotis. The number of bat recordings per detector-hour (as a measure of relative activity) was highest at Lower Inonoaklin and lowest at Mosquito Creek. Data collected to date provide baseline information on the site-level and regional variation in bat species composition and activity, which are needed for future assessments of bat response to wildlife physical works.

Our ability to address each of the management questions is summarized below.

MQ	Able to Address MQ?	Scope		Sources of Uncertainty/Limitations
		Current supporting results	**Suggested modifications to methods where applicable**	
1. Are the revegetation and the wildlife physical works projects effective at enhancing wildlife habitat in the drawdown zone?	Partially	Data collected in control, treatment, and upland reference sites indicate that wildlife are using all treatment areas. Current results show little difference between control and treatment plots.	• Continue to focus assessments of revegetation effectiveness where prescriptions are most successfully established i.e., Lower Inonoaklin, Edgewood South etc. • Conduct pre-treatment sampling prior to physical works implementation for all taxa (where possible, e.g., Burton Creek).	• Due to lack of pre-treatment sampling, it is unknown if revegetation has enhanced wildlife habitat in the drawdown zone. • Natural annual population variation and seasonality • Lack of replication • Mixed success of revegetation program • Previous bi-annual sampling • Variable reservoir operations • Physical works have not been implemented

MQ	Able to Address MQ?	Scope		Sources of Uncertainty/Limitations
		Current supporting results	Suggested modifications to methods where applicable	
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?	Partially	To date, revegetation prescriptions do not appear to effectively improve wildlife habitat. In general, no multi-year trend has been observed for arthropod biomass or songbird communities between the control and treatment areas within sites.	• Continue annual sampling • Nest searching for songbirds was initiated in 2016. Increase nest search effort to better measure bird productivity • Continue monitoring with autonomous recording units, targeting areas of proposed wildlife physical works • Conduct pre-treatment sampling prior to physical works implementation for all taxa (where possible, e.g., Burton Creek).	• Lack of appropriate baseline (sampling did not occur prior to the application of the revegetation prescriptions) • Natural annual population variation and seasonality • Lack of replication • Mixed success of revegetation program • Previous bi-annual sampling • Variable reservoir operations • Physical works have not been implemented
3. Are some methods or techniques more effective than others at enhancing wildlife habitat in the drawdown zone?	Partially	Revegetation treatments were most successfully established at Lower Inonoaklin and Edgewood South. Whether this is due to the treatment types applied or site-specific variation is not known.	• Consider adding replicates of certain revegetation prescriptions. • Increase the size (total area treated) of some existing revegetation areas.	• Lack of appropriate baseline (sampling did not occur prior to the application of the revegetation prescriptions) • Natural annual population variation and seasonality • Lack of replication • Mixed success of revegetation program • Variable reservoir operations

Key Words: Arrow Lakes Reservoir, songbirds, arthropods, bats, revegetation, effectiveness monitoring, drawdown zone, hydro

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ACRONYMS AND DEFINITIONS

To ensure that readers of this report interpret the terminology used throughout, the following definitions are provided.

Revegetation Area: areas revegetated under CLBWORKS-2 between 2009 and 2011.

Revegetation Prescription: the prescriptions implemented in the revegetation areas. Only certain revegetation prescriptions were considered for monitoring (because of replication and total area treated). For simplicity, these were categorized as:

EPL: excavator-planted live stake

EPL/HPL: excavator-planted live stake and hand-planted live stake

HPL: hand-planted live stake

PS: plug seedling

Study Site: refers to a broad geographic area of the reservoir used as the highest level of stratification for sampling. The sites, from north to south, are shown in Figure 3-1. They are Beaton Arm, East Arrow Park, Mosquito Creek, Burton Creek, Lower Inonoaklin Road, Edgewood North and Edgewood South.

Habitat Type: Within each site, sampling was conducted in control, treatment, drawdown zone and reference polygons, collectively referred to as habitat types. The habitat types were referred to as “treatments” in previous reports, and are defined as follows:

Control: area of the drawdown zone that was not revegetated using the revegetation prescriptions developed for CLBWORKS-2. Control polygons were placed in areas of similar elevation, topography and substrate as treatment polygons, to serve as untreated paired controls within the study sites that were revegetated.

Treatment: area of the drawdown zone that was revegetated using one of the seven revegetation prescriptions developed for CLBWORKS-2.

Drawdown Zone: area of the drawdown zone (≤ 440.1 m ASL) in a study site lacking revegetation treatment. Drawdown zone sampling areas were similar to controls, but occurred in study sites without revegetation prescriptions. These data contribute to baseline data, should treatments be applied and also contribute to our understanding of the regional, natural variation in taxa in terrestrial habitats influenced by reservoir inundation.

Reference: sampling areas outside of the drawdown zone (> 440.1 m ASL) and adjacent to control and treatment sites. One of the functions of the reference sites is to allow for interpretation of naturally occurring changes in the relative abundance, diversity, richness or other metric associated with one or more of the focal groups over time. These are monitored to assess regional and natural variation in the taxa being studied in non-reservoir areas. In particular, changes in community composition between study years in reference sites provide insight into inter-annual variation not due to reservoir operations (e.g., taxon phenology, climate, regional disturbance).

Experimental Block: pairing of a treatment polygon with a control polygon. The experimental block established at sites where revegetation prescriptions were applied consists of the revegetation polygon and a control polygon that is the same size and configuration as the treatment polygon.

1.0 INTRODUCTION

The Columbia River Water Use Plan was developed as a result of a multi-stakeholder consultative process to determine how to best operate BC Hydro's Mica, Revelstoke and Keenleyside facilities to balance environmental values, recreation, power generation, culture/heritage, navigation and flood control. The goal of the Water Use Plan is to accommodate these values through operational means (i.e., patterns of water storage and release) and non-operational physical works in lieu of changing reservoir operations to address specific interests. During the Water Use Planning process, the Consultative Committee supported the implementation of physical works (revegetation and habitat enhancement) in the mid-Columbia River in lieu of changing reservoir operations to help mitigate the impact of Arrow Lakes Reservoir operations on wildlife and wildlife habitat. In addition, the Consultative Committee recommended the use of monitoring to assess the effectiveness of these physical works in enhancing habitat for wildlife.

This recommendation resulted in the development of CLBMON-11B1, an 11-year monitoring program comprised of two distinct components:

1. CLBMON-11B: Revegetation effectiveness monitoring; and
2. CLBWORKS-29B: Wildlife enhancement prescriptions for mid- and lower Arrow Lakes Reservoir.

These two components were combined to assess the efficacy of revegetation prescriptions, to enhance wildlife habitat using a focal species approach, and to identify opportunities to enhance the suitability of wildlife habitat in the drawdown zone of mid- and lower Arrow Lakes Reservoir.

An effectiveness monitoring program should be designed to determine how well management activities, decisions, or practices meet the stated objectives of the program (Marcot 1998, Noon 2003). Key to designing an effectiveness monitoring program is the selection of sensitive and readily measurable response variables that are appropriate to the objectives of the management action (Machmer and Steeger 2002); however, the selection of indicators (e.g., focal species) can be challenging (Andersen 1999). The selection of indicator species/processes should be guided by their sensitivity to the management practice, the ease of collecting data, and the usefulness of the information to address the management activity (Chase and Guepel 2005). Potential indicators may include habitat attributes, keystone species, species at risk, species that are sensitive to specific habitat requirements, or species that can be monitored easily (Feinsinger 2001, Chase and Guepel 2005). The selection of indicators should also be appropriate to the spatial scale of the applied management activity, and must take into consideration factors that are external to the monitoring program, such as inter- and intra-specific competition, predation, climatic change, disease, time of year, and in the case of CLBMON-11B1, normal reservoir operations.

In 2009, LGL completed a reconnaissance-level study of wildlife using the drawdown zone of Arrow Lakes Reservoir; the study focused on terrestrial arthropods, songbirds and mammals. The results of that study are presented in Hawkes et al. (2010). The second year of monitoring occurred in 2010 (see Hawkes et al. 2011), in 2011 (Hawkes et al. 2012) and again in 2013 (Hawkes et al. 2014). A report discussing the utility of ungulate pellet plot surveys was completed in year five by Adama and Hawkes (2015). This report summarizes results from the seventh year of monitoring (2016) of CLBMON-11B1 and includes information on the use of the drawdown zone mainly by terrestrial arthropods, songbirds, and bats and the relationship of those species groups to the various revegetation prescriptions applied between 2009 and 2011 (CLBWORKS-2). Options for wildlife enhancement strategies (i.e., CLBWORKS-29B) were discussed in the following reports (Hawkes and Howard 2012, Hawkes and Tuttle 2016). CLBWORKS-29B provides prescriptions to improve wildlife habitat in and immediately adjacent to the drawdown zone of mid- and lower Arrow Lakes Reservoir.

2.0 OBJECTIVES AND MANAGEMENT QUESTIONS

Two projects, CLBMON-11B and CLBWORKS-29B, are collectively captured under the umbrella of CLBMON-11B1. The objectives of CLBMON-11B (modules 1 and 2[1]) are to determine the efficacy of revegetation efforts and wildlife habitat enhancement or protection efforts in increasing the suitability of wildlife habitats in the drawdown zone of mid- and lower Arrow Lakes Reservoir. The enhancement prescriptions developed for mid- and lower Arrow Lakes Reservoir (CLBWORKS-29B) will be designed to either protect existing habitat features that provide high-value wildlife habitat or to enhance/create those features within the drawdown zone. CLBMON-11B involves acquiring data on mammals, songbirds and terrestrial arthropods.

The Water Use Plan Consultative Committee provided the following direction with respect to the revegetation and wildlife physical works effectiveness monitoring program (BC Hydro 2007):

Project Description: To monitor wildlife utilization patterns in response to revegetation efforts in Kinbasket Reservoir, Mid-Columbia River and Arrow Lakes Reservoir.

Rationale: “There is uncertainty about current utilization of the drawdown zone by wildlife species and the effects of reservoir operations. Monitoring will inform on the effects of revegetation efforts in Kinbasket and Arrow Lakes Reservoirs on wildlife utilization patterns and the effectiveness of Arrow Lakes Reservoir physical works on wildlife habitat quality and quantity”.

The overall scope of this study is to address whether revegetation and wildlife physical works are effective in enhancing wildlife habitat in lieu of changing reservoir operations.

The combined objectives of CLBMON-11B1 are as follows:

1. Develop a monitoring program to assess the effectiveness of the revegetation program (CLBWORKS-2) and wildlife physical works projects (CLBWORKS-30) in enhancing wildlife habitat in the drawdown zone of Arrow Lakes Reservoir.

[1] CLBMON-11B2 is focused on the monitoring of neotropical migrant songbirds in relation to the effectiveness of revegetation and wildlife physical works projects in Revelstoke Reach (for e.g., Craig and Cooper 2017).

2. Monitor the appropriate biological indicators and response variables to assess the effectiveness of the revegetation and wildlife physical works programs in enhancing wildlife habitat in the drawdown zone.
3. Provide recommendations on the effectiveness of the revegetation program and wildlife physical works projects in improving habitat for wildlife in the drawdown zone.
4. Identify high-value habitat along the drawdown zone of the lower and middle reaches of the Arrow Lakes Reservoir for protection.
5. Identify habitat enhancement opportunities along the drawdown zone of the lower and middle reaches of the Arrow Lakes Reservoir.
6. Provide recommendations for enhancing or protecting high-value wildlife habitat along the drawdown zone of the lower and middle reaches of the Arrow Lakes Reservoir.
7. Prepare a minimum of three habitat enhancement/restoration plans.

2.1 Management Questions

CLBMON-11B1 is designed to assess the wildlife habitat effectiveness of the revegetation program (CLBWORKS-2), guide the development of CLBWORKS-30, and assess the effectiveness of the resulting wildlife physical works in enhancing wildlife habitat in the drawdown zone of Arrow Lakes Reservoir. Monitoring under CLBMON-11B1 will evaluate the response of several wildlife taxa and habitat elements to alterations made to the drawdown zone by the revegetation and wildlife physical works programs. The findings of this study will help improve the effectiveness of revegetation and physical works projects through the use of an adaptive management approach.

This monitoring program will address three management questions:

1. Are the revegetation and the wildlife physical works projects effective at enhancing wildlife habitat in the drawdown zone?
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?
3. Are some methods or techniques more effective than others at enhancing wildlife habitat in the drawdown zone?

2.2 Management Hypotheses

The hypotheses address the revegetation and wildlife physical works projects independently and will address the management questions listed above.

HA_1: Revegetation does not change wildlife use of the drawdown zone.

HA_{1A}: Revegetation does not change the area (m^2) or increase the suitability of wildlife habitat in the drawdown zone.

HA_{1B}: Revegetation does not change the utilization of the drawdown zone by songbirds as measured by species diversity and/or relative abundance.

HA_{1C}: Revegetation does not change the utilization of the drawdown zone by ungulates as measured by indices of use (e.g., pellet counts, browse, tracks and occupancy).

HA_{1D}: Revegetation does not change the utilization of the drawdown zone by amphibians and reptiles as measured by occupancy and/or relative abundance (e.g., presence/absence and catch per unit effort).

HA_{1E}: Revegetation does not change the abundance (e.g., biomass) and species diversity in the drawdown zone of terrestrial arthropods, which are prey for amphibians and reptiles, birds and mammals.

HA_{2}: Wildlife physical works does not change wildlife use of the drawdown zone.

HA_{2A}: Wildlife physical works projects do not change the area (m^2) or increase the suitability of wildlife habitat in the drawdown zone.

HA_{2B}: Wildlife physical works projects do not change the utilization of the drawdown zone by birds (including raptors, songbirds, waterbirds and shorebirds) as a measure of increased species diversity, abundance and productivity.

HA_{2C}: Wildlife physical works projects do not change the utilization of the drawdown zone by Painted Turtles and other amphibians and reptiles as a measure of occupancy, abundance and productivity (e.g., presence/absence, catch per unit effort, breeding success).

HA_{2D}: Wildlife physical works projects do not change the abundance (e.g., biomass) and species diversity in the drawdown zone of invertebrates, which are prey for amphibians and reptiles, birds and mammals.

HA_{3}: The methods and techniques employed do not result in changes to wildlife habitats in the Arrow Lakes Reservoir drawdown zone.

HA_{3A}: The revegetation methods do not result in changes to wildlife habitat in the drawdown zone as measured by indices of habitat suitability, site productivity (e.g., arthropod biomass) and forage production.

HA_{3B}: The methods used for wildlife physical works do not result in changes to wildlife habitat in the Arrow Lakes Reservoir drawdown zone as measured by indices of habitat suitability, site productivity (e.g., arthropod biomass) and forage production.

The hypotheses and objectives of this study are more easily discussed in terms of broad themes that encapsulate the hypotheses and objectives for CLBMON-11B or CLBWORKS-29B (Table 2-1).

Table 2-1: The broad themes and hypotheses addressed by each theme for each component of CLBMON-11B1. An X indicates a relationship between the theme and hypothesis. Bold and shading indicates the focus of this annual report

Theme and Component		Hypotheses													
		HA_1	HA_{1A}	HA_{1B}	HA_{1C}	HA_{1D}	HA_{1E}	HA_2	HA_{2A}	HA_{2B}	HA_{2C}	HA_{2D}	HA_3	HA_{3A}	HA_{3B}
1. Revegetation, wildlife and wildlife habitat	**11B**	**X**	**X**	**X**	**X**	**X**	**X**								
2. Revegetation and changes to productivity	**11B**													**X**	
3. Revegetation: a comparison of techniques	**11B**												**X**		
4. Physical works	29B							X	X	X	X	X			X

2.3 Key Water Use Decisions Affected

The Terms of Reference for CLBMON-11B1 indicate that the results of this study will aid in more informed decision-making with respect to the need to balance the requirements of wildlife that are dependent on wetland and riparian habitats with other values such as recreational opportunities, flood control and power generation. The key water use planning decisions affected by the results of this monitoring program are whether revegetation and wildlife physical works are more effective in enhancing wildlife habitat than are changes to reservoir operations. Results from this study will also assist in refining the approaches and methods for enhancing wildlife habitat through adaptive management.

3.0 STUDY AREA

The Hugh Keenleyside Dam, completed in 1968, impounded two naturally occurring lakes to form the Arrow Lakes Reservoir, an approximately 230-km long section of the Columbia River drainage between Revelstoke and Castlegar, B.C. (Figure 3-1; Carr et al. 1993, Jackson et al. 1995). Two biogeoclimatic zones occur within the study area: the Interior Cedar Hemlock (ICH) and the Interior Douglas-fir (IDF). The reservoir has a north-south orientation, and is set in the valley between the Monashee Mountains in the west and Selkirk Mountains in the east. Arrow Lakes Reservoir has a licensed storage volume of 7.1 million acre feet (BC Hydro 2007). The normal operating range of the reservoir is between 418.64 m and 440.1 m above sea level (m ASL).

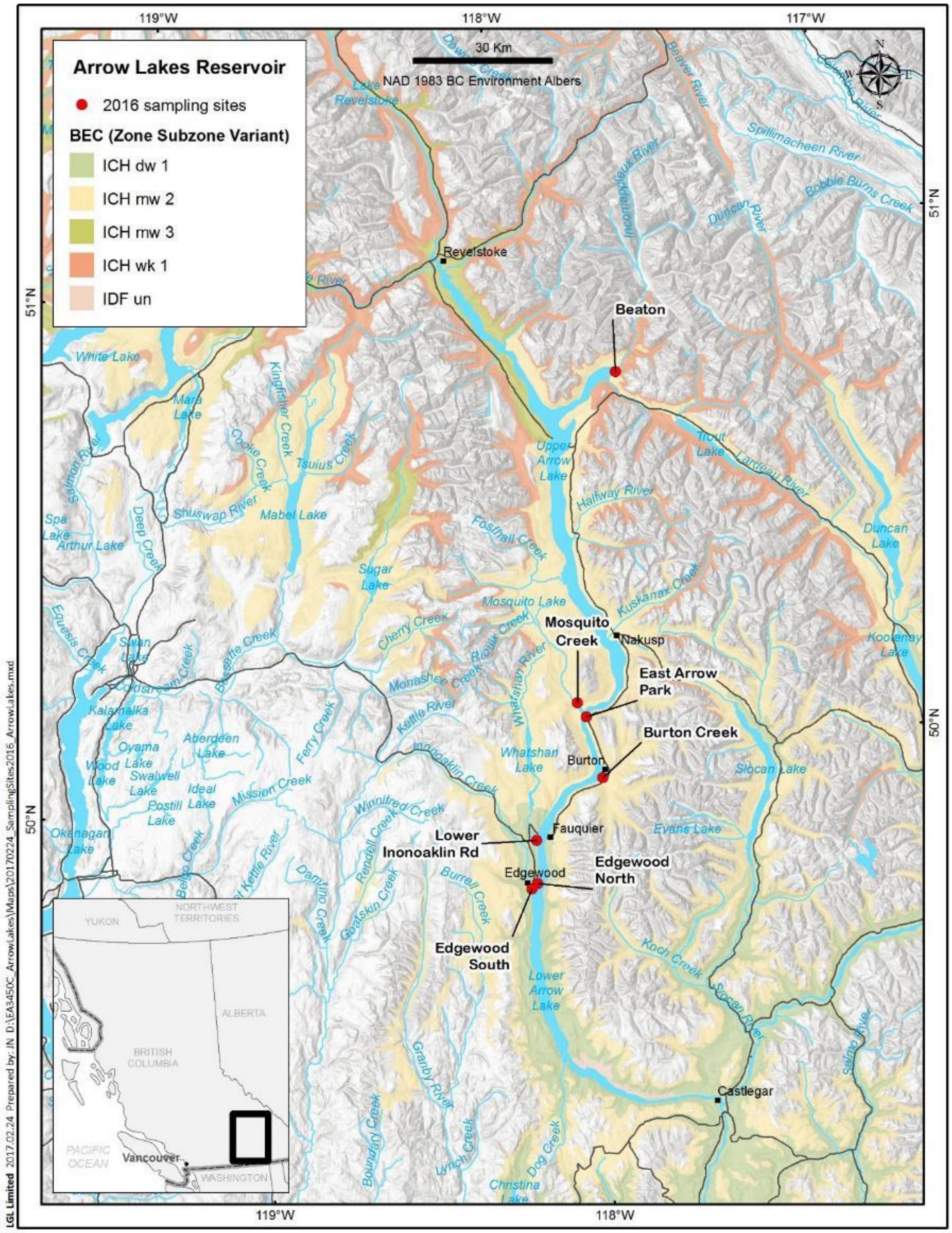

Figure 3-1: Location of 2016 study sites within Arrow Lakes Reservoir in B.C.

For CLBMON-11B1, the area of interest within Arrow Lakes Reservoir is the drawdown zone between Beaton Arm and Castlegar (Figure 3-1).

Since 2010, seven areas within the drawdown zone of Arrow Lakes Reservoir have been selected for monitoring (Figure 3-1). Site selection was based on those areas treated under CLBWORKS-2 (Keefer et al. 2009), on areas within the drawdown zone that will not be treated under CLBWORKS-2 where potential wildlife enhancement projects could occur, and areas that represent habitats in the drawdown zone that could be considered climax communities (relative to those that could develop in the drawdown zone). These sites were monitored again in 2016, though not all project components were sampled at all sites (Table 3-1).

Table 3-1: List of sites sampled in each year from 2009 to 2016. "X": all taxa were sampled; "O": songbird surveys only; "-": no sampling occurred. Note: sampling for bats is not reflected in this table

Site Name	2009	2010	2011	2013	2015	2016
Edgewood South	X	X	X	X	X	X
Edgewood North	X	X	X	X	X	O
Lower Inonoaklin	-	-	O	O	O	X
Burton Creek	X	X	X	X	X	X
East Arrow Park	X	X	X	X	-	O
Mosquito Creek	X	X	X	X	X	O
Beaton Arm	X	X	X	X	X	O

4.0 METHODS

4.1 Revegetation Treatments

Revegetation prescriptions (CLBWORKS-2) were applied between 2008 and 2011 and the total area revegetated per year ranged from 2.13 ha in 2008 to 36.22 ha in 2009 (see ACRONYMS AND DEFINITIONS). The plug seedling prescription was the most commonly applied prescription (39.84 ha) followed by hand-planted live stakes (23.31 ha). All other prescriptions were either applied either over relatively small areas or in one year only. Both plug seedling and live stakes prescriptions were used in all sites sampled for CLBMON-11B1. Examples of the types of revegetation prescriptions applied in the drawdown zone of Arrow Lakes Reservoir are detailed in Hawkes et al. (2014). Vegetation growing in revegetated areas of the drawdown zone at Burton Creek, Edgewood South, and Lower Inonoaklin were sampled from July 23 to 28, 2016. Vegetation were characterized using veg plot data collected from 5m^2 plots, noting the number and condition of cottonwood stakes present. Cottonwood stakes were categorized depending on their condition: "live" indicating they were alive but showed no current, annual growth; "live and growing" indicating they were alive and had observable buds, leaves, or flowers; and "dead", indicating the stem was completely dead. Stakes found lying on the ground were categorized as "dead".

4.2 Terrestrial Arthropods

4.2.1 Arthropod Collection

Terrestrial arthropods were sampled with pitfall trap arrays and Malaise traps using methods consistent with those described in previous years of this study [e.g., Hawkes et al. 2011, 2014; Sharkey et al. 2016 (draft)] and provincial RIC standards (1998). In 2016 (as with 2015), we sampled in June and July to coincide with songbird sampling. As in previous years, not all habitat types were available in each site sampled (Table 4-1). Five pitfall arrays were established in each habitat type (treatment, control, drawdown zone, reference). Pitfall arrays were comprised of three traps (473 mL clear plastic Amcor® food cups inserted into the ground) spaced 1 m apart at randomly determined sampling locations. Sampling locations were randomly selected within each treatment or control polygon in GIS by first overlaying a 5 m x 5 m grid on the polygon and then randomly selecting each grid cell for sampling.

One Malaise trap was also installed in each control, treatment, drawdown zone, and reference habitat (where available). Sampling locations were standardized between years and selected based on field topography and best practice methodologies outlined in provincial RIC standards (1998). Maps depicting the location of pitfall and Malaise traps in 2016 are provided in Appendix A.

Traps were filled with ~100 mL of preservation fluid (99% Propylene glycol, Univar Canada Ltd.), and all traps were checked daily to ensure functionality and record trap disturbance. After approximately 48 hours, samples were collected for assessments of arthropod biomass (‘biomass samples’), with contents of individual pitfall traps pooled within each array to generate five biomass pitfall trap samples and one malaise trap sample for each habitat polygon. Traps were immediately serviced and filled with preservation fluid and a second collection was made after an additional ~24 hours of sampling time. These one-day samples were collected for assessments of arthropod diversity (‘diversity samples’). Similarly, contents from individual pitfall traps were pooled into one pitfall trap sample for each array, resulting in five pitfall diversity samples and one malaise diversity sample per habitat polygon. This sampling protocol was repeated in two survey periods: June 18 to 25, and July 11 to 18, 2016.

Total sampling effort was 946.9 trap-days (Malaise: 55.7 trap-days; pitfall: 891.3 trap nights; Table 4-1). Animal disturbance and/or weather affected sampling effort in some cases, due to reduced trap functionality, and were accounted for in effort calculations.

Table 4-1: Sampling effort (trap-days) by site and habitat type for each sample type and trapping method employed in the Arrow Lakes Reservoir. Columns are ordered logically such that the product of column 5 through 8 results in the sum shown in column 9. Samples represent pooled pitfall trap (P) samples and single Malaise trap (M) samples. *mean time for a single trap (one Malaise or one pitfall in an array); **total time given per trap type and sample type in each habitat

Study Site	Habitat Polygon	Sample Type	Trap Type	24-hr Days per Trap*	No. of Traps per Sample	No. of Samples	No. of Collection Periods	Sum of Trap-Days**
BU	**BU01 T**	Biomass	M	1.5	1	1	2	3.0
			P	2.0	3	5	2	60.5
		Diversity	M	1.0	1	1	2	2.0
			P	1.0	3	5	2	29.8
	BU02 T	Biomass	M	1.5	1	1	2	3.0
			P	1.9	3	5	2	57.2
		Diversity	M	0.7	1	1	2	1.5
			P	1.0	3	5	2	29.4
	BU01 C	Biomass	M	1.2	1	1	2	2.5
			P	2.0	3	5	2	60.2
		Diversity	M	1.0	1	1	2	2.0
			P	1.0	3	5	2	29.9
	BU02 C	Biomass	M	1.9	1	1	2	3.8
			P	1.9	3	5	2	58.2
		Diversity	M	1.0	1	1	2	2.0
			P	1.0	3	5	2	29.4
	BU R	Biomass	M	2.0	1	1	2	3.9
			P	2.0	3	5	2	58.7
		Diversity	M	1.0	1	1	2	2.0
			P	1.0	3	5	2	29.3
ES	**ES T**	Biomass	M	2.0	1	1	2	4.0
			P	2.0	3	5	2	59.5
		Diversity	M	1.0	1	1	2	2.0
			P	0.9	3	5	2	27.0
	ES C	Biomass	M	2.0	1	1	2	3.9
			P	2.0	3	5	2	59.4
		Diversity	M	1.0	1	1	2	2.1
			P	1.0	3	5	2	30.8
	ES R	Biomass	M	2.0	1	1	2	3.9
			P	2.0	3	5	2	58.6
		Diversity	M	1.0	1	1	2	2.1
			P	1.0	3	5	2	31.4
LI	**LI T**	Biomass	M	2.0	1	1	2	3.9
			P	2.0	3	5	2	59.3
		Diversity	M	1.1	1	1	2	2.1
			P	1.1	3	5	2	32.1
	LI C	Biomass	M	2.0	1	1	2	3.9
			P	2.0	3	5	2	58.6
		Diversity	M	1.1	1	1	2	2.1
			P	1.1	3	5	2	31.7
TOTAL								**946.9**

4.2.2 Sample Processing and Identification

With the aid of taxonomic specialists, arthropods from diversity samples were counted and dominant taxa groups were classified to the lowest taxonomic level feasible. Diptera, Coleoptera, and Hymenoptera were classified to the family level. Orthoptera and Araneae were identified to species because of their potential use as indicators to assess habitat changes associated with the application of revegetation prescriptions in the drawdown zone of mid- and lower Arrow Lakes Reservoir.

The biomass samples were weighed and placed in a drying oven for an average of 48 hours. The dried samples were weighed again to obtain the dry weight of each sample. The contents of the biomass samples were not tallied, sorted, or identified in 2016 due to the time intensive nature of this work. Rather, the biomass of each taxon group was extrapolated from the composition given by the diversity samples (see Hawkes et al. 2012, 2014). The biomass associated with each trap type, habitat type, site, and collection was kept separate for comparative purposes.

4.3 Songbirds

Time-constrained, variable-radius[2] point count surveys were used to assess the diversity and relative abundance of songbirds (Ralph et al. 1995). The timing of the songbird surveys (mid-June to mid-July) coincided with the height of the breeding season at which time all locally breeding birds are on territory and are highly vocal, enabling surveyors to document the number and diversity of breeding birds. Two visits to each point count were attempted in 2016: the first between June 18 and June 25, and the second between July 11 and July 18. Surveys commenced at sunrise and ended within ~4 hours of sunrise (Ralph et al. 1995). Songbird surveys were done during favourable conditions only (i.e., no heavy wind or precipitation) to standardize surveys and minimize variable detections associated with sub-optimal environmental conditions. All songbird surveys conformed to the provincial standard (RIC 1999).

The point count survey method involved standing at a fixed point within each control, treatment, and reference site and documenting all birds seen and/or heard within 75 m of the observer during a 6-minute count period. Individual point counts were placed at ~150 m intervals to reduce multiple detections of the same bird from more than one point count station during each survey. The species of bird as well as the distance (from the observer) were recorded. Additional data recorded included the sex and age class of the bird (when known) and the type of detection (call, song, or visual), and notes were made to differentiate fly-over birds from the rest of the detections. Furthermore, because the detectability of different bird species varies depending on the amount of time devoted to each survey (Bibby et al., 2000), the portion of the 6-minute count period in which each individual is detected was recorded (0-3 minutes, 3-5 minutes, 5-6 minutes).

At each point count station, the following data were collected:

1. **Physical information:** site number, point count number, GPS coordinates, weather (wind speed, temperature, relative humidity [measured with a Kestrel® 4000 Pocket Weather Meter], current survey conditions), date, time of day, visit number;
2. **Bird observations (sight or sound) in point count plots:** species, approximate age (adult/juvenile), and location of each bird heard or seen within point count plot, location mapped on point count form, estimate of the horizontal distance between each detected bird and the observer, detection type (sight or sound);

[2] Variable in the sense that data are recorded at varying distances from the point count centre

3. **Bird observations outside point count plots:** incidental observations of birds located outside the point count area at each site.

4.4 Bats

There are potentially 12 species of bat in the West Kootenays, but the number of live-capture studies has been insufficient to confirm the presence of at least one of those [Western Small-footed Myotis (*Myotis ciliolabrum*)]. Five species are of conservation concern at the provincial and/or national level. In BC, Townsend's Big-eared Bat (*Corynorhinus townsendii*), Western Small-footed Myotis, Northern Myotis (*M. septentrionalis*), and Fringed Myotis (*M. thysanodes*) are blue-listed by the BC Conservation Data Centre (CDC), which is a status assigned to species that are particularly sensitive to impacts from human activities or natural events (BC CDC 2017). Federally, Northern Myotis and Little Brown Myotis (*M. lucifugus*) were emergency listed under the Species at Risk Act as Endangered (Dec. 17, 2014) due to the potential threat of White Nose Syndrome (COSEWIC 2013). White Nose Syndrome is caused by a fungus (*Pseudogymnoascus destructans*) that has been spreading westward since it was first documented in North America. Fringed Myotis is considered Data Deficient by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) which means there is not enough scientific information available to support status designation at this time.

Table 4-2: Provincial and national status of bat species that potentially occur in the Lower and Mid-Arrow Lakes area

Common Name	Scientific Name	Code	Present	CDC Status	COSEWIC Status	SARA
Townsend's Big-eared Bat	*Corynorhinus townsendii*	COTO	Yes	Blue		
Big Brown Bat	*Eptesicus fuscus*	EPFU	Yes	Yellow		
Hoary Bat	*Lasiurus cinereus*	LACI	Yes	Yellow		
Silver-haired Bat	*Lasionycteris noctivagans*	LANO	Yes	Yellow		
California Myotis	*Myotis californicus*	MYCA	Yes	Yellow		
Western Small-footed Myotis	*Myotis ciliolabrum*	MYCI	Unverified	Blue		
Long-eared Myotis	*Myotis evotis*	MYEV	Yes	Yellow		
Little Brown Myotis	*Myotis lucifugus*	MYLU	Yes	Yellow	Endangered	1-E (2014)
Northern Myotis	*Myotis septentrionalis*	MYSE	Yes	Blue	Endangered	1-E (2014)
Fringed Myotis	*Myotis thysanodes*	MYTH	Yes	Blue	Data Deficient	3 (2005)
Long-legged Myotis	*Myotis volans*	MYVO	Yes	Yellow		
Yuma Myotis	*Myotis yumanensis*	MYYU	Yes	Yellow		

Fourteen Wildlife Acoustics SM2BAT+ autonomous recording units were deployed to study bat presence and distribution over and adjacent to the drawdown zone, from early May to late September 2016 (Appendix C). Each unit was programmed with a schedule to document bats during two periods: (1) half an hour before sunset for 5.5 hours, and (2) an hour before sunrise for 1.5 hours, for a total of 7 hours per 24 hour period. Reservoir drawdown zone sites sampled by bat detector units include: Beaton Arm (n=1), Burton Creek (n=3), Edgewood South (n=3), Lower Inonoaklin (n=2), and Mosquito Creek (n=1). Non-reservoir reference sites included: Armstrong Lake (n=1), Box Lake (n=1), and a natural wetland located at West Arrow, south of Mosquito Creek (n=2). One bat detector sampling each control and live stake treatment at Edgewood South, Burton Creek, and Lower Inonoaklin. An additional bat detector was deployed for pre-treatment sampling of proposed physical works locations at Edgewood South and Burton Creek. Non-reservoir reference sites were included to compare bat diversity and relative abundance at sites not affected by reservoir operations to those in or adjacent to the drawdown zone.

Under ideal conditions SM2BAT+ detectors will sample bats in an airspace of 30 to 100 m from the microphone, with bats emitting higher frequencies (e.g., *Myotis septentrionalis)* detected more often in the 30 m zone and bats emitting lower frequencies (e.g., *Lasionycteris noctivagans* and *Lasiurus cinereus)* detected up to ~100 m from the microphone. The microphone paired with the SM2BAT+ is omnidirectional, meaning that it will sample from almost all directions projecting out from the microphone. The microphones were set at a height of ~2 m above ground or higher, attached to either expandable aluminum poles or tree branches, and the pitch of the microphone was set at approximately 90° (horizontal). Detectors were positioned to sample within each treatment when possible, but given the size of some treatments, this was not always the case (see Appendix C).

4.5 Terrestrial Mammals

Incidental mammal observations (visual sightings, wildlife signs) were recorded between June 19 to 25 and from July 11 to 28, 2016. Although incidental observations do not include information about effort which limits analysis value, they are important, especially in long term studies to understand the distribution and habitat use of animals. The location of species observed, and mammal sign (e.g., bones, hair, and scat) in the drawdown zone and upland locations were recorded. This general approach was consistent with the methods used by Hawkes et al. (2010, 2011a, 2012, 2013). We also documented the location of unique wildlife habitat features, such as mineral licks or animal dens. Occasionally, bycatch of small mammals and amphibians occurred during arthropod pitfall trapping. Such specimens were collected in Whirl-Pak® sampling bags with preservative, labelled and stored in a freezer until identified using a microscope and key (Naughton 2012).

4.6 Amphibians and Reptiles

Amphibian and reptile observations (visual sightings) were documented by observers while performing other surveys, or as part of directed surveys which are presented in CLBMON-37 (e.g., Hawkes and Tuttle 2013; Hawkes et al. 2015). Occasionally, bycatch of amphibians occurred during arthropod pitfall trapping. Such specimens were collected in Whirl-Pak® sampling bags with preservative, labelled and stored in a freezer until identified.

4.7 Data Analyses

In general, data analyses followed those performed in recent years (e.g., Sharkey et al. 2016 (draft); Hawkes et al. 2014). Most of the results reported summarize the data collected in 2016 and do not represent a detailed assessment of temporal trends. The analyses performed in 2016 aimed to do the following:

1. continue to characterize the fauna (i.e., songbirds, arthropods, mammals, and amphibians and reptiles) in the drawdown zone of mid- and lower Arrow Lakes Reservoir;
2. compare (where possible) the relative abundance and species richness of songbirds and arthropods among the various combinations of sites and treatments between years;

3. relate the biomass of certain orders of arthropods (those eaten by insectivorous songbirds) to the songbird species that would prey on those orders; and
4. determine if the songbird and arthropod assemblages associated with drawdown and adjacent upland habitats documented in previous years (2009, 2010, 2011, 2013, and 2015) persisted in 2016.

4.7.1 Revegetation Treatments

Vegetation data were summarized by site. Total stake counts were totalled and a success rate calculated based on the total number of stakes assessed. Vegetation data collection was not extensive for the entire study area, and is presented here as supplementary information.

4.7.2 Terrestrial Arthropods

Relative abundance and biomass were assessed as per Sharkey et al. (2016, draft). Relative abundance was calculated as catch-per-unit-effort (CPUE), equal to the number of arthropods caught per trap, standardized to a 10-hour trapping period.

Biomass (mg/hour) values were assessed by site, trap type, treatment and year in bar graphs and box plots. Boxplot graphs are a useful way of visualizing differences between groups of ecological data, showing dispersion and skewness without making any assumptions about their underlying statistical distributions (Sokal and Rohlf 1995).

To test for statistical differences in biomass among habitat types, Kruskal-Wallis rank sum tests were performed. The Kruskal-Wallis rank sum test is a non-parametric alternative to analysis of variance (ANOVA), which is appropriate for ecological data (such as the biomass data) that fails to pass the assumptions of ANOVA. Post-hoc pairwise tests were corrected for multiple comparisons with the Bonferroni adjustment (α=0.10/ no. of comparisons). Kruskal-Wallis tests were performed using the R agricolae package (de Mendiburu 2014).

Composition and assemblage similarity were assessed with methods similar to previous years. Two resemblance coefficients were used to measure differences in composition between sites and treatments: Bray-Curtis Dissimilarity (D14) and Hellinger Distance (D17). Both of these coefficients involve a transformation of each element of species-abundance data in a sample x species data table, called a general relativization. D14 involves a relativization of species-wise differences by the total abundance of species in two plots being compared. Thus, the abundance of each species is transformed to a proportion of the species total abundance. This makes the differences between abundant species contribute the same to D14 as differences between rare species.

D17 performs best for linear ordination, such as PCA (Legendre and Legendre 1998) and involves transformation whereby each species observation is relativized by the total abundance of that species across all surveys, followed by a square root transformation (Legendre and Gallagher 2001); the application of the Euclidean distance measure to this Hellinger-transformed species abundance is known as Hellinger Distance (Legendre and Legendre 2012). The percent similarity in taxa composition between sites was calculated with the Sørensen similarity coefficient (Sørensen 1948), as follows:

$$\% \text{ Sørensen Similarity} = 2C / (A + B),$$

where A is the number of taxa present in site one, B is the number of taxa present in site two, and C is the number of taxa present in both site one and site two. This coefficient was chosen because it gives higher weight to taxa presences, which is more informative because species absences do not necessarily reflect environmental differences (Legendre and Legendre 2012).

To examine patterns in arthropod taxa collected in 2016, we performed Principal Components Analysis (PCA) using the Hellinger distance measure applied on standardized abundance (catch per trap per 24 hours). PCA provides a summary of linear relationships between samples (sites and habitat types) and taxa, including the total variance in composition across all samples. Taxa correlations with treatments and sites were overlaid on PCA ordinations as biplots, where the angles between descriptor axes describe the strength and direction of correlation. An angle of < 90° between two taxon vectors implies correlation, whereas vectors ≥ 90° from each other are said to be orthogonal and not correlated. Additionally, 90% confidence ellipses were plotted to examine differences in composition between treatments. Ordination plots were provided for each PCA to show the relationships between taxa and samples. Data were constrained to the trapping method appropriate for targeting each focal taxon, such that Malaise trap data was used when analysing Hymenoptera and Diptera, whereas pitfall trap data was used for Araneae, Coleoptera, and Orthoptera. All ordinations were performed using the vegan package for community ecology (Oksanen et al. 2016) in the R language (R Core Team 2016).

To examine spider species assemblages over multiple years, we performed Principal Coordinates Analysis (PCoA), the Kendall Coefficient of Concordance *W*, K-means partitioning, and PCA. These analyses were performed on the raw abundance of spider species from pitfall trap samples in five years: 2010, 2011, 2013, 2015, and 2016.

Kendall's *W* is a method to identify groups of significantly associated species (or other taxon level) in species-abundance data (Legendre 2005; Legendre and Legendre 2012). First, an overall test of independence is performed for all taxa. Second, if the overall test is significant (taxa are not independent), then groups of correlated taxa are found using a K-means partitioning technique. Third, within each group, the contribution of each species to the overall W statistic is tested with permutation tests. This method searches for species associations without any reference to the sites or treatments from which the samples are drawn. Instead, this method aims to find the *smallest* number of groups containing the largest number of positively associated species. To calculate concordance *W* and K-means partitioning, only species that occurred in at least two sites or treatment types were included in the analyses. The *W* coefficient and K-means partitions were tested with 100,000 permutations.

Multivariate Regression Trees (MRT; De'ath 2002) reveal informative partitions in ecological community datasets for multiple taxa as response variables to a suite of environmental predictor variables (in our case: year, study area, site, and habitat type). MRT analyses were performed using standardized abundances to account for uneven sampling, with the Hellinger distance measure in the MVPART package in R (De'ath 2014). The MVPART option 'pca=T' was used to generate the PCA ordinations that correspond to groups in the MRTs.

Indicator Analyses (Dufrêne and Legendre 1997) were conducted to assess characteristic species (or families) of each group resolved by the Multivariate Regression Tree (MRT) analyses. Prior to indicator analysis, individual taxa were grouped according to nodes and branches reflected in MRTs. Thus, indicator analyses were performed on these defined groups to highlight the taxa responsible for the variation in assemblages in the MRTs (Pinzon and Spence 2010; Work et al. 2013).

An indicator value (IndVal) was calculated for each species j in each group k (in our case, each node of the MRT). The IndVal is the product of two values, A_{kj} and B_{kj}. A_{kj} is a measure of species specificity (based on relative abundance), whereas B_{kj} is a measure of species fidelity (based on relative frequency of occurrence) across each sample. The inclusion of both the specificity and fidelity is an important requirement for identifying reliable indicator taxa. For example, high specificity alone defines "characteristic taxa" but without consideration of fidelity, these species may be limited in their distribution across sampling points. Useful indicators occur reliably among sampling units belonging to a treatment type or site.

Taxa were considered indicators for a given treatment when its indicator value (IndVal) was significantly different from random ($\alpha = 0.05$) after a Monte Carlo test based on 9,999 permutations. IndVals range from zero (no indication) to 1 (perfect indication). We present all indicator taxa with significant IndVal greater than 0.25, following the suggestions of Dufrêne and Legendre (1997).

All Indicators species analyses (ISAs) were performed in the labdsv package in R (Roberts 2016).

4.7.3 Songbirds

Songbird analyses are typically limited to songbird (i.e., passerines) detections within 75 m of the point count centre. Songbird analyses follow Sharkey et al (2016, draft) with respect to constraining the data set to 75 m from the point count centre for some analyses and data within 30 m of the point count centre for others. Birds detected as fly-overs are excluded from analyses, as these individuals may not be utilizing the treatment area containing the point count; the exception being swallows, swifts and hummingbirds which are included as they are aerial foragers and almost exclusively detected as they fly overhead.

The following analyses were completed only for songbirds, and swifts, swallows, and hummingbirds to (1) provide an overview of the avifauna documented from each site and treatment sampled in 2016; (2) highlight differences in species richness, relative abundance, community similarity, and songbird assemblages in and adjacent to the drawdown zone of Arrow Lakes Reservoir; (3) compare data collected between 2009 and 2015 to those collected in 2016; and (4) continue to assess species of songbirds that may be suitable focal species for monitoring the effectiveness of revegetation prescriptions applied in the drawdown zone of Arrow Lakes Reservoir. Maps depicting the location and distribution of songbird point count stations for each site and treatment sampled in 2016 are provided in Appendix B.

Relative abundance, richness, diversity analyses followed those described in Hawkes et al. (2014). Data was summarized per point count, and corrected for the number of visits (i.e., if a point count was surveyed in three visits, the abundance, richness, and diversity was divided by three to remain comparable to point counts receiving fewer visits). The statistical unit was the point count, which are replicated within habitats, sites, and years.

Relative abundance was calculated as the number of observations meeting the above criteria, per point count station, divided by the number of surveys. Similarly, richness (q) was calculated as the total number of songbird species detected per point count station, divided by the number of surveys. Shannon's entropy index (H) was calculated for songbirds as described in Legendre and Legendre (2012).

Shannon's entropy (H) provides a measure of diversity, as follows:

$$H = -\sum_{i=1}^{q} p_i \log p_i$$

where q is species richness and p_i is the relative frequency or proportion (on a 0 to 1 scale) of observations in species i. For a given survey occasion, H is maximum when the observations are equally distributed among the q species, H is lower when one or a few species exhibit stronger dominance, and H= 0 when there is only one species detected. H increases with the number of species and thus, has no predefined maximum.

Corrected species richness, relative abundance, and diversity were compared among years, treatment types, and sites with boxplots. Statistical tests were performed with two-way unbalanced crossed-factor ANOVA tests with 9999 permutations using Pierre Legendre's function 'anova.2way.unbalanced.R' (Legendre, 2015). This method computes ANOVA test statistics with distance-based redundancy analysis (RDA; Anderson and Legendre 1999; Legendre and Anderson 1999). Several significance tests were computed in series for comparisons among treatments, among years, among sites and years (where data was subset for each habitat type). These analyses were conducted for two sets of bird data: i) restricted to observations within 75 m of point count stations and ii) restricted to observations within 30 m of point count stations. P-values were not adjusted for multiple comparisons. Results of statistical tests were considered significant at α=0.10.

Species composition, assemblage similarity and indicator analyses were assessed using the same methods outlined for arthropods in section 4.7.2; please refer to that section for methodological details. In addition, to correlate availability of arthropods to songbird species in each site and treatment, PCA ordinations were generated with overlays of the biomass of arthropods and bird species for the 2016 pitfall and Malaise trap samples.

4.7.4 Bats

The acoustic signatures of many bat species overlap in their frequency ranges making it difficult to confidently differentiate some species based solely on recordings (Table 4-3; also Szewczak et al. 2011a,b). Bat presence and activity was therefore assessed by analyzing recordings from Wildlife Acoustics SM2BAT+ units using their proprietary automatic ID software, Kaleidoscope Pro v. 4.0.4. Kaleidoscope is a quick and effective tool for the analysis of a large volume of recordings and results are easily exported for further analysis. Kaleidoscope utilizes classifiers developed from libraries of species-verified recordings to generate complex algorithms used in the automated identification process. Species classifiers can be selected to match the known or expected bat fauna in an area. The classifiers for 11 species that have been confirmed for the West Kootenays were selected for use in auto ID analysis of 2016 data. Additionally, Western Small-footed Myotis, which appears to be limited to dry, low elevation valleys in the interior of British Columbia (Garcia *et al.* 1995), was recommended for inclusion only at Edgewood South as it is likely only to be detected at this site (C. Lausen, PhD, Wildlife Conservation Society Canada, pers. comm.). Auto ID analysis is intended for use on recordings of single bats in a low clutter environment. Sampling locations were selected to minimize clutter, but some environmental (e.g., rain, wind, surface echoes, temperature changes, etc.) and biological (e.g., number of bats present, distance of bats, etc.) factors cannot be controlled. Recording quality is consequently variable and can result in misclassifications, thus we present our bat detections as indicative rather than definitive.

Table 4-3: Typical frequencies (kHz) of calls from bat species expected to occur in habitats associated with the drawdown zone of the Lower and Mid-Arrow Lakes Reservoir

Species	Frequency (kHz)		
	Characteristic (f_c)	Highest Apparent (Hi *f*)	Lowest Apparent (Lo *f*)
Corynorhinus townsendii	21 - 26	40 - 45	19 - 23
Eptesicus fuscus	27 - 30	50 - 63	26 - 29
Lasiurus cinereus	18 - 22	21 - 31	18 - 22
Lasionycteris noctivagans	26 - 27	33 - 50	24 - 27
Myotis californicus	47 - 51	89 - 111	43 - 47
Myotis ciliolabrum	42 - 46	86 - 104	39 - 42
Myotis evotis	33 - 36	64 - 93	26 - 31
Myotis lucifugus	39 - 42	63 - 86	36 - 40
Myotis septentrionalis	40 - 47	95 - 114	32 - 42
Myotis thysanodes	23 - 26	57 - 88	17 - 22
Myotis volans	39 - 44	78 - 101	34 - 40
Myotis yumanensis	47 - 52	77 - 103	44 - 47

The species richness of bat species was summarized for each site and the relative level of activity (determined by the number of recordings attributed to a given species per detector hour) was assessed. Temporal activity (by hour and month) was also calculated. Data collected by autonomous recording devices do not provide an indication of the number of individual bats present in a given area and the assignment of species is based on a probability that the species is present.

4.7.5 Terrestrial Mammals

Data analyses for terrestrial mammals were limited to an assessment of the distribution of incidental species by site and sign type. Because few mammal observations in the drawdown zone were within revegetation or control polygons, comparisons between control and treatment sites were not possible. Data are presented for the 2016 monitoring sessions.

4.7.6 Amphibians and Reptiles

No data analyses are presented for amphibians and reptiles in this report. For a full report on this group please refer to CLBMON-37 (e.g., Hawkes and Tuttle 2013; Hawkes et al. 2015). Species documented within and adjacent to the drawdown zone of Arrow Lakes Reservoir are presented here.

5.0 RESULTS

5.1 Reservoir Conditions

The elevation of Arrow Lakes Reservoir ranged from a low of 434.42 m ASL during field session 2 to a high of 436.70 m ASL during field session 1 (Table 5-1).

Table 5-1: Dates and reservoir elevations of each 2016 field session (FS). A = available; NA = not available

	2016		Reservoir Elevation (m ASL)			Strata Elevation (m ASL)			
						Lowest	Low	Medium	High
FS	Start Date	End Date	Min	Max	Mean	< 434	434–436	436–438	> 438
1	June 18	June 25	436.18	436.70	436.44	NA	NA	A	A
2	July 11	July 18	434.42	435.17	434.80	NA	A	A	A

Reservoir elevations in 2016 were lowest in January to February, hitting the lowest yearly point (424.14 m ASL) on January 31, 2016 (Figure 5-1). Water levels increased after that, peaking on June 10, 2016 (437.24 m ASL). Following peak reservoir elevation water levels dropped steadily until October at which time they increased again. In 2016 the reservoir levels were lower than in most previous years, reaching minimum and maximum elevations earlier, although overall the yearly pattern of reservoir elevation fluctuations has been relatively consistent since 2008 (Figure 5-1).

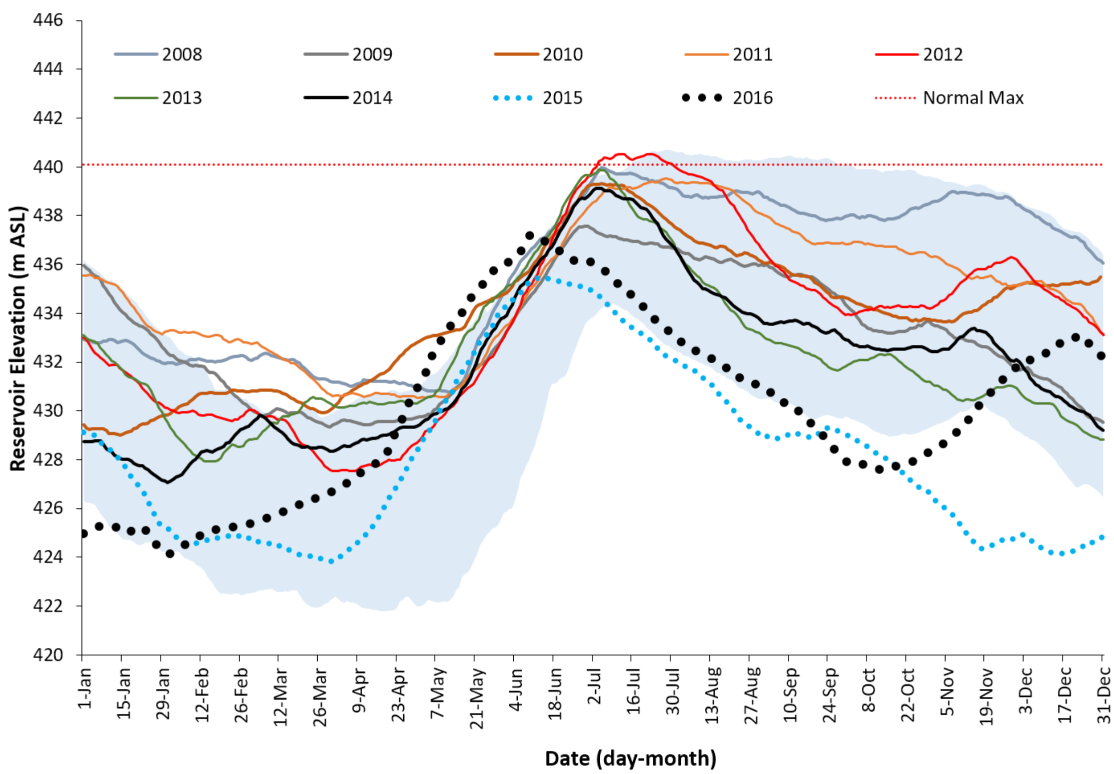

Figure 5-1: Arrow Lakes Reservoir elevations for 2008 to 2016. The 10th and 90th percentiles are shown for 1969-2016 (shaded area); m ASL= metres above sea level

5.2 Revegetation Treatments

A total of 35 vegetation plots were sampled at Burton Creek, Edgewood South, and Lower Inonoaklin. The success rate of Cottonwood stakes (number of live stakes divided by the total number of stakes) ranged from 18.4 to 44.6 per cent, varying by location (Table 5-2). The success rate of these planted Cottonwood stakes is expected to decline over time, as few (13.4 per cent) live stakes showed sign of current growth. Recreational vehicle (i.e., truck and ATV) use was also noted at Lower Inonoaklin, which may cause damage to vegetation in the area.

Table 5-2: Number and condition of Cottonwood stakes planted at Burton Creek, Edgewood South, and Lower Inonoaklin. Data refer only to the survivorship in the plots sampled, not the treatment overall. See Miller et al. (2016) for more information

Site	No. of Plots	Cottonwood Stakes			
		Live	Live and Growing	Dead	Success Rate (%)
Burton	4	14	0	62	18.4
Edgewood South	13	415	129	1319	29.2
Lower Inonoaklin	18	615	33	738	44.6
Total	*35*	*1044*	*162*	*2119*	*35.4*

5.3 Arthropods

A total of 195 taxa were documented from all sites and treatments sampled in and adjacent to the drawdown zone of Arrow Lakes Reservoir in 2016. Specimens were collected from 20 orders (including one subclass and two class determinations), 130 families and 45 species. As in previous years, pitfall traps captured more taxa (*n*=117 taxa) than Malaise traps (*n*=106).

5.3.1 Relative abundance and Richness

Standardized arthropod abundance (number of individuals caught per 10 hour period) varied largely by trapping method with Malaise trapping yielding higher catch per unit effort (CPUE) than pitfall trapping (Figure 5-2). At Burton Creek the malaise trap sample from BU02 (PS: plug seedling) treatment and the pitfall trap sample from BU01 (EPL/HPL: excavator/hand-planted live stake) treatment were the only areas where treated areas had higher relative abundance than control or reference areas (Figure 5-2). For all other sites, regardless of trapping method the relative abundance of arthropods was higher in control areas than treatment areas. Suggesting there is no treatment effect or possibly a negative treatment effect. The relative abundance of arthropods was lower in the upland reference areas sites at all sites and trap types.

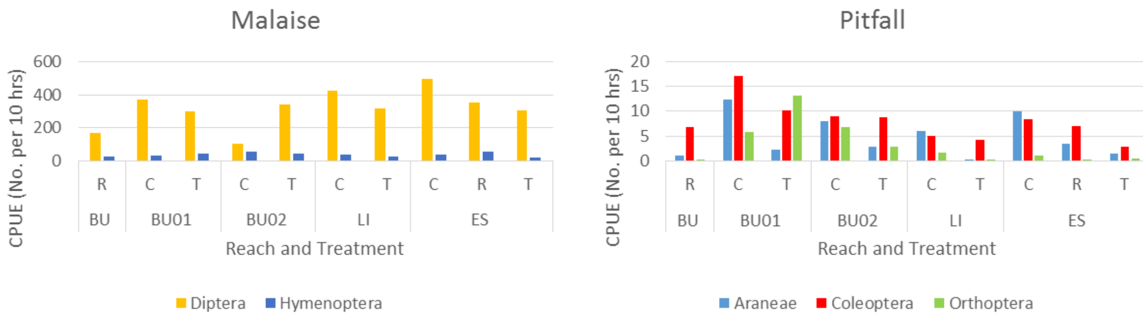

Figure 5-2: Abundance of arthropods (CPUE: catch per unit effort) assessed for Malaise traps and pitfall traps for each site and treatment sampled in 2016 in mid- and lower Arrow Lakes Reservoir. Note the difference in y-axis between trap types. Sites are ordered from North to South of the reservoir. BU: Burton Creek (BU01: treatment 1; BU02: treatment 2); EWS: Edgewood South; LI: Lower Inonoaklin

In 2016 we identified 35 species of spiders from thirteen families. There has been a decrease in the number of species and families each sampling year from a high of 87 species of 19 families in 2010 to the lowest number of species and families recorded in 2016 (Figure 5-3). This is likely a result of decreased trapping effort and geographical changes in sampling during recent years of study.

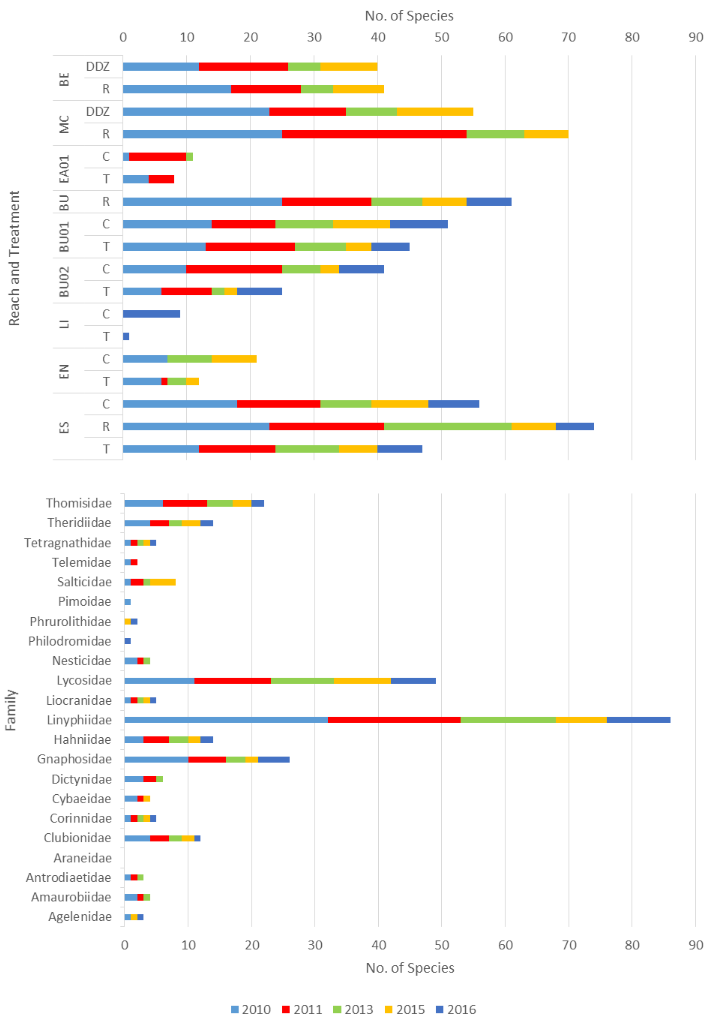

Figure 5-3: Total number of spider species documented at sites in the mid- and lower Arrow Lakes Reservoir in 2010, 2011, 2013, 2015 and 2016. Data from all spider families are pooled in the top panel and data from all sites and treatments are pooled in the bottom panel. Richness not standardized for unequal trapping effort between years

Unstandardized species richness of spiders varied between site and treatment (Figure 5-3). In general, there were more spider species in controls than revegetation treatments, and upland reference areas housed the most spider species. For example, at Lower Inonoaklin in 2016, nine spider species occurred in the control polygon versus only one species in the revegetation treatment.

5.3.2 Biomass

Arthropod biomass (mg/hr) were compared by site, treatment, year and trap type for 2015 and 2016 data. Overall, the biomass of aerial arthropods collected in Malaise traps was greater in 2015, compared to 2016 (Edgewood South and Burton). This inter-annual variation in biomass was also reflected in reference sites, and thus likely not due to variable operation of the reservoir levels. Patterns in biomass across treatments were variable, depending on site. In 2016, Edgewood South (ES) and Burton (BU02) treatment biomass was lower than the ES and BU02 controls (Figure 5-4). In the absence of baseline (pre-treatment) sampling, we are unable to draw causal conclusions to treatment differences.

A Kruskal-Wallis rank sum test was performed comparing biomass means by year (2015 and 2016) and treatment for each trap type. In 2015, Malaise biomass values were not different between control and reference plots and in 2016 Malaise biomass values were not different between treatment and reference plots. In 2016, control plots had significantly greater biomass than treatment plots. ($H= 21.89$, $df= 6$, $p< 0.001$).

Overall, ground-dwelling arthropod biomass was similar between years (2015 and 2016) for pitfall trap samples (Figure 5-5). Within sites, treatment biomass was lower than controls, except for at the BU01 site in 2015.

A Kruskal-Wallis rank sum test was performed comparing biomass means by year (2015 and 2016) and treatment for pitfall traps. Mean ranks of biomass were not different between years for control plots or for reference plots. In 2016, control plots had significantly greater biomass than treatment plots. No difference in mean biomass was observed between treatment plots in 2015 and 2016 ($H= 31.27$, $df= 6$, $p< 0.001$).

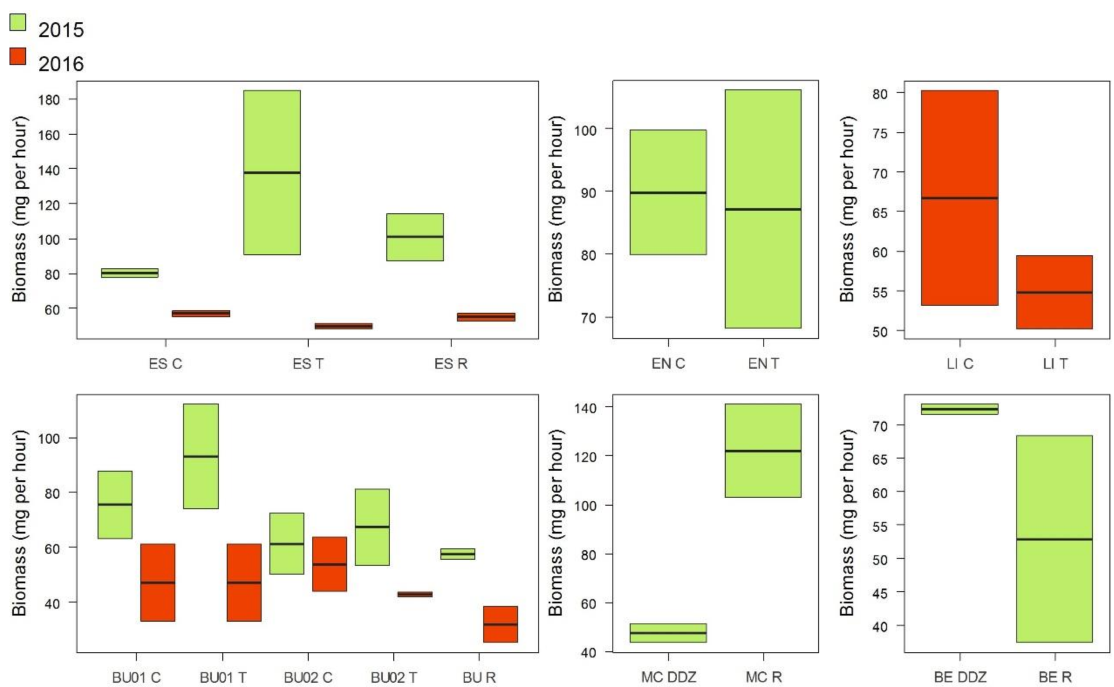

Figure 5-4: Malaise arthropod biomass (mg/hr) for each site and treatment sampled in the Arrow Lakes Reservoir in 2015 and 2016 (n= 2). Note the difference in y-axis between sites. Not all sites were trapped in each year. BE: Beaton Arm; MC: Mosquito Creek; BU: Burton Creek (BU01: treatment 1; BU02: treatment 2); LI: Lower Inonoaklin; EN: Edgewood North; ES: Edgewood South. DDZ: drawdown zone; R: reference site; C: Control site; T: treatment site

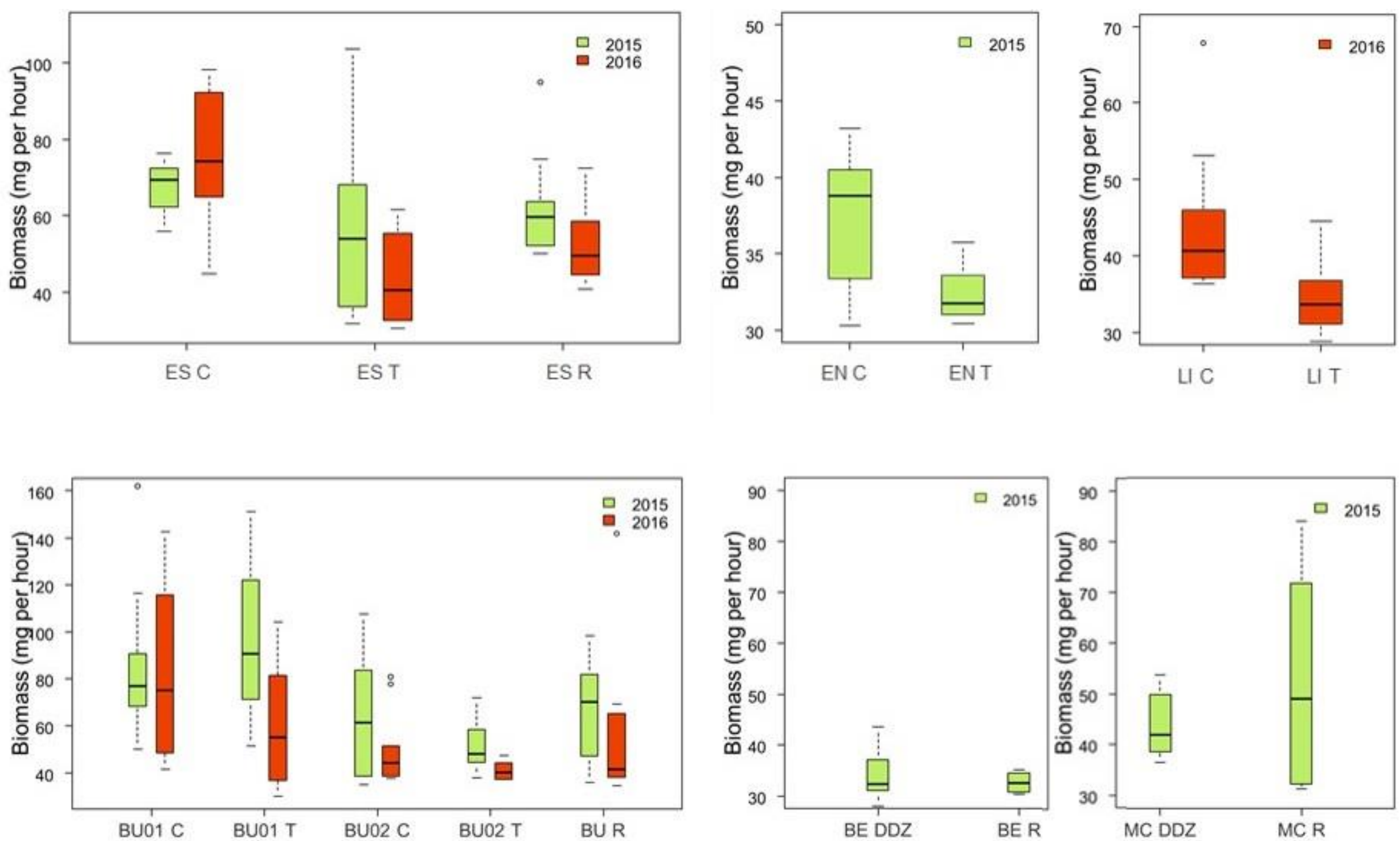

Figure 5-5: Biomass of arthropods (mg/hr) from pitfall traps grouped per site, treatment type, and year in Arrow Lakes Reservoir (n=5). Boxplots show median values (solid horizontal line), 25th and 75th quartiles (box outline), max and min values (whiskers) and outliers (circle). Note the difference in y-axis between sites. Not all sites were sampled in both years. BU: Burton Creek (BU01: treatment 1; BU02: treatment 2); EWN: Edgewood North; EWS: Edgewood South; LI: Lower Inonoaklin; BE: Beaton Arm; MC: Mosquito Creek. C: Control; T: Treated; R: Reference, DDZ: Drawdown zone.

5.3.3 Arthropod assemblage composition and similarity

Consistent with the results of previous years, Arthropod assemblages did not form any specific patterns with respect to revegetation treatment and control areas in Malaise or pitfall trap samples. Thus, there is no apparent effect of revegetation on aerial or ground-dwelling arthropods.

Diptera assemblages from 2016 Malaise trap samples were comprised of 15,639 flies in 47 different families. Overall, two axes of the PCA ordination explained 84% of the variation in fly family composition (Figure 5-6). Composition was similar between controls and treatments (overlapping 90% confidence ellipses), but different between these drawdown zone sites and the upland reference. Patterns in the abundance of certain families explains these patterns in the fly community. In particular, Cecidomyiidae ('Gall and Wood Midges') were strongly associated with reference sites at Burton Creek and Edgewood South, while Chironomidae ('Midges'), Muscidae ('House Flies and kin'), and Dolicopodidae ('Long-legged Flies'), were associated with control and treatment sites (collectively).

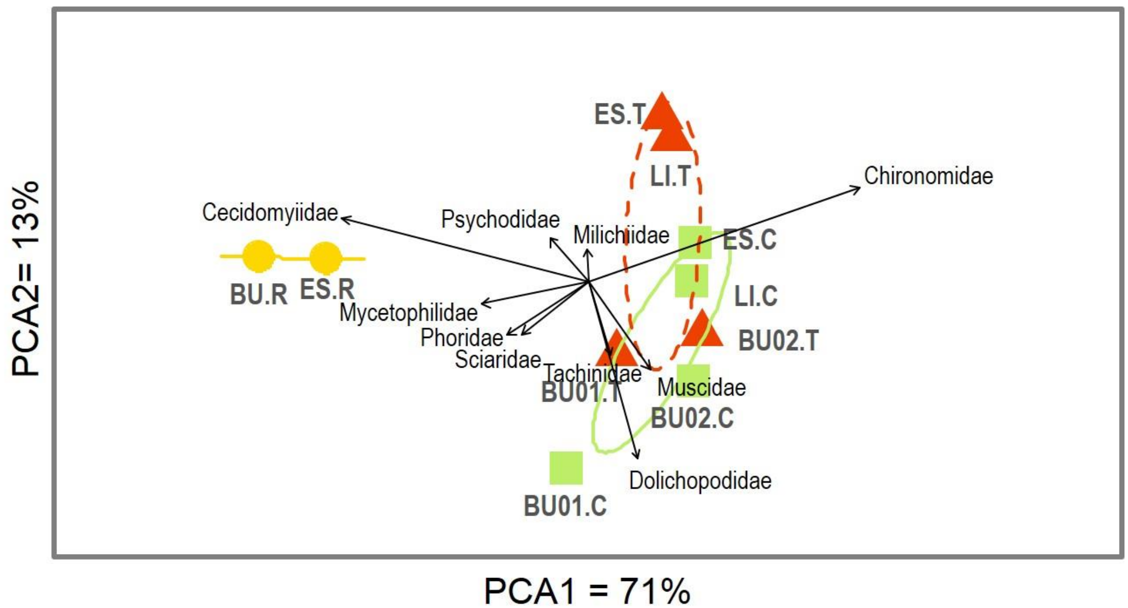

Figure 5-6: Principal Components Analysis (PCA) ordination of Diptera family assemblages collected in Malaise traps in 2016, showing relationships among treatments and sites. Abundance was standardized by trap effort and distances were computed with the Hellinger distance measure. Confidence ellipses (90% CI) are overlaid for treatment comparisons: revegetation treatment (orange, T), control (green, C), upland reference (yellow, R). Vectors are overlaid for select taxa to assess the direction and strength of association with each site and treatment. Site codes: BU= Burton, ES= Edgewood South, LI= Lower Inonoaklin

Hymenoptera assemblages from 2016 Malaise trap samples contained 1,661 bees, wasps, and ants in 36 different families. Overall, two axes of the PCA ordination explained 61% of the variation in Hymenoptera family composition (Figure 5-7). Composition was similar between controls and treatments (overlapping 90% confidence ellipses), but different between these drawdown zone sites and the upland reference. Upland reference sites were correlated with the standardized abundance of minute parasitic wasps in the family Diapriidae. Diapriids are typically found in wooded areas with decaying vegetation and fungi, where the larvae parasitize fungus gnats and other flies. The drawdown zone plots were characterised by associations with other families including two families of parasitic wasps (Pteromalidae, Proctotrupidae) and one family of generalist predators [Sand and Digger wasps (Crabronidae)].

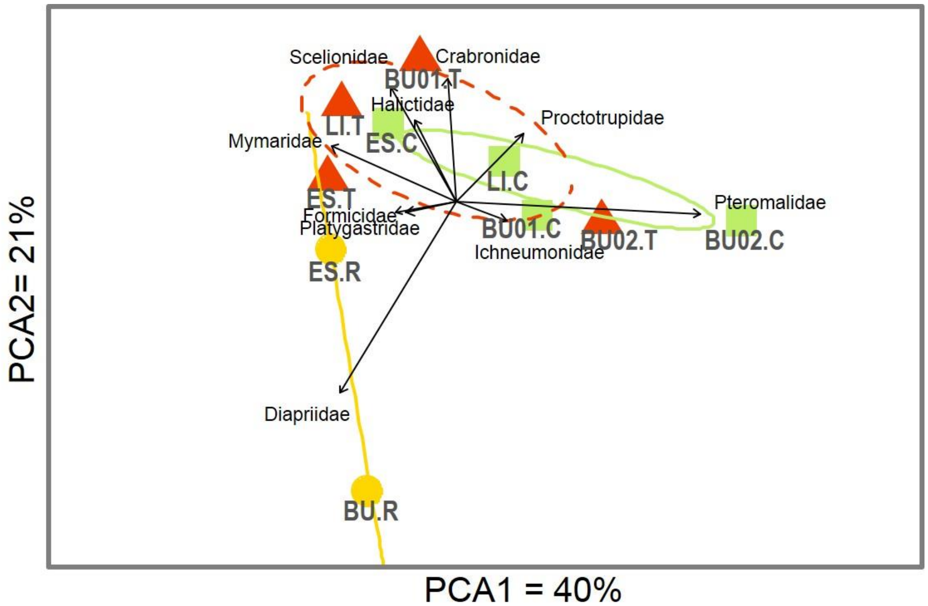

Figure 5-7: Principal Components Analysis (PCA) ordination of Hymenoptera family assemblages collected in Malaise traps in 2016, showing relationships among treatments and sites. Abundance was standardized by trap effort and distances were computed with the Hellinger distance measure. Confidence ellipses (90% CI) are overlaid for treatment comparisons: revegetation treatment (orange, T), control (green, C), upland reference (yellow, R). Vectors are overlaid for select taxa to assess the direction and strength of association with each site and treatment. Site codes: BU= Burton, ES= Edgewood South, LI= Lower Inonoaklin

Orthoptera assemblages in 2016 pitfall traps were comprised of 9 species from 767 individuals of Grasshoppers and Crickets. Orthoptera species assemblages separated largely along PCA axis 1, forming distinct communities between reference sites and the drawdown zone (treatment and control plots; Figure 5-8). The Camel Cricket, *Pristoceuthophilus celatus*, was strongly associated with reference sites, with only one individual collected in a non-reference plot (at Edgewood South control). Overall, species composition was similar between controls and treatments (overlapping 90% confidence ellipses), although particular species and site-specific associations were evident. For example, the treatment and control plots at Lower Inonoaklin housed distinct orthopteran communities, sharing no species in common between treatment and control. These plots separated along PCA axis 2. The Migratory Grasshopper, *Melanoplus sanguinipes*, which prefers open sunny habitats with herbaceous plant cover, was strongly associated with the Lower Inonoaklin treatment. In contrast, the Orthoptera found in Lower Inonoaklin control were similar to those found in other drawdown zone sites (Striped Ground Cricket, *Allonemobius fasciatus,* and Slender Grouse Locust, *Tetrix subulata*). Treatment differences could be due to revegetation success and / or pre-existing site-specific differences between the treatment and control areas at Lower Inonoaklin.

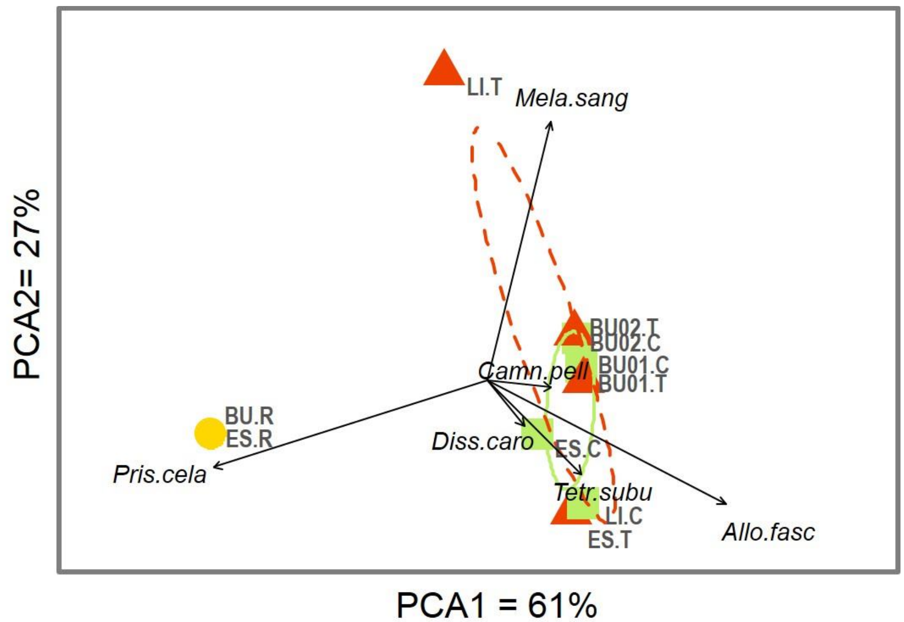

Figure 5-8: Principal Components Analysis (PCA) ordination of Orthoptera species assemblages collected in pitfall traps in 2016, showing relationships among treatments and sites. Abundance was standardized by trap effort and distances were computed with the Hellinger distance measure. Confidence ellipses (90% CI) are overlaid for treatment (orange, T) and control (green, C) plots, which were distinct from reference communities (yellow, R). Species vectors are overlaid for select species to assess the direction and strength of association with each site and treatment. Site codes: BU=Burton, ES= Edgewood South, LI=Lower Inonoaklin; Species codes: *Camn.pell= Camnula pellucida, Diss.caro= Dissosteira carolina, Mela.sang= Melanoplus sanguinipes, Allo.fasc= Allonemobius fasciatus, Pris.cela= Pristoceuthophilus celatus, Tetr.subu= Tetrix subulata*

Coleoptera assemblages in 2016 pitfall traps contained 20 families of beetles and a total of 1,849 individuals. Coleoptera assemblages were explained largely by PCA axis 1 (explains 54% of the variance in Hellinger distance), forming distinct communities between reference sites and the drawdown zone (treatment and control plots; Figure 5-9). In general the beetle family composition of BU01 control was most similar to the reference sites at Edgewood South and Burton, driven by the greater abundance of 'Weevils and Bark Beetles' (Curculionidae), 'Round Fungus Beetles' (Leiodidae), and 'Silken Fungus Beetles' (Cryptophagidae) at those sites. BU01 control and treatment had 78.3% of their beetle families in common (Sørensen similarity coefficient). Similar to previous years' results (Hawkes et al. 2015), beetle composition was similar between controls and treatments (overlapping 90% confidence ellipses). Within the drawdown zone plots, beetle family assemblages were most distinct between the control at treatment at Lower Inonoaklin in 2016, sharing 66.7% of their beetle families in common (Sørensen similarity coefficient). These plots separate along PCA axis 2, with LI treatment correlated with standardized abundance of Anthicidae (Ant-like

Flower Beetles) and Elateridae (Click Beetles). LI control was correlated with standardized abundance of Chrysomelidae (Leaf Beetles). These composition differences between revegetation treatment and control at Lower Inonoaklin could be indicative of arthropod response to the revegetation success, though in the absence of pre-treatment sampling, it is possible that these areas inherently house different arthropod communities due to site-specific differences (e.g., differences in soil moisture, substrate, topography, nutrients, salinity, etc.).

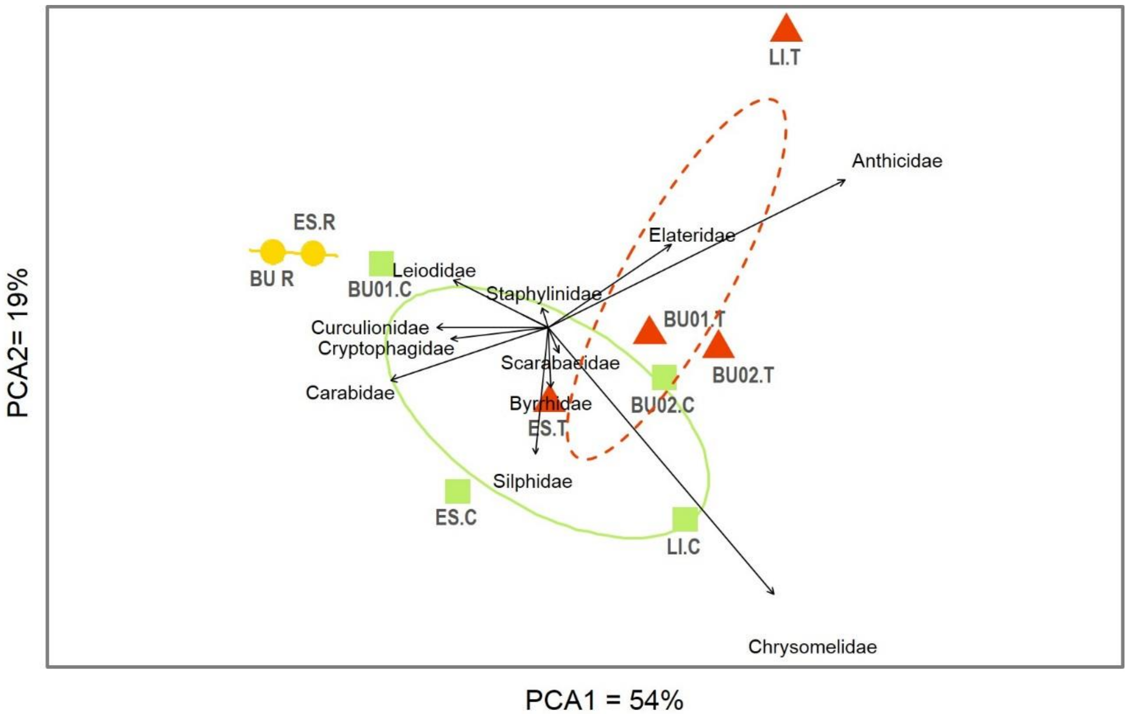

Figure 5-9: Principal Components Analysis (PCA) ordination of Coleoptera family assemblages collected in pitfall traps in 2016, showing relationships among treatments and sites. Abundance was standardized by trap effort and distances were computed with the Hellinger distance measure. Confidence ellipses (90% CI) are overlaid for treatment comparisons: revegetation treatment (orange, T), control (green, C), upland reference (yellow, R). Vectors are overlaid for select taxa to assess the direction and strength of association with each site and treatment. Site codes: BU= Burton, ES= Edgewood South, LI= Lower Inonoaklin

Araneae assemblages from 2016 pitfall trap sampling contained 381 adult spiders (Araneae) identified to 34 species. Overall, two axes of the PCA ordination explained 47% of the variation in spider species composition (Figure 5-10). The composition of spiders was similar between treatment and control plots (based on Hellinger distance of standardized abundance). Only reference communities were distinct from the drawdown zone communities. The outlying treatment at Lower Inonoaklin only caught one adult spider (*Walckenaeria vigilax*), which is a new record for our monitoring in Arrow Lakes reservoir (not previously recorded during sampling). However, little can be concluded for the spider composition at the LI treatment due to low catch in 2016.

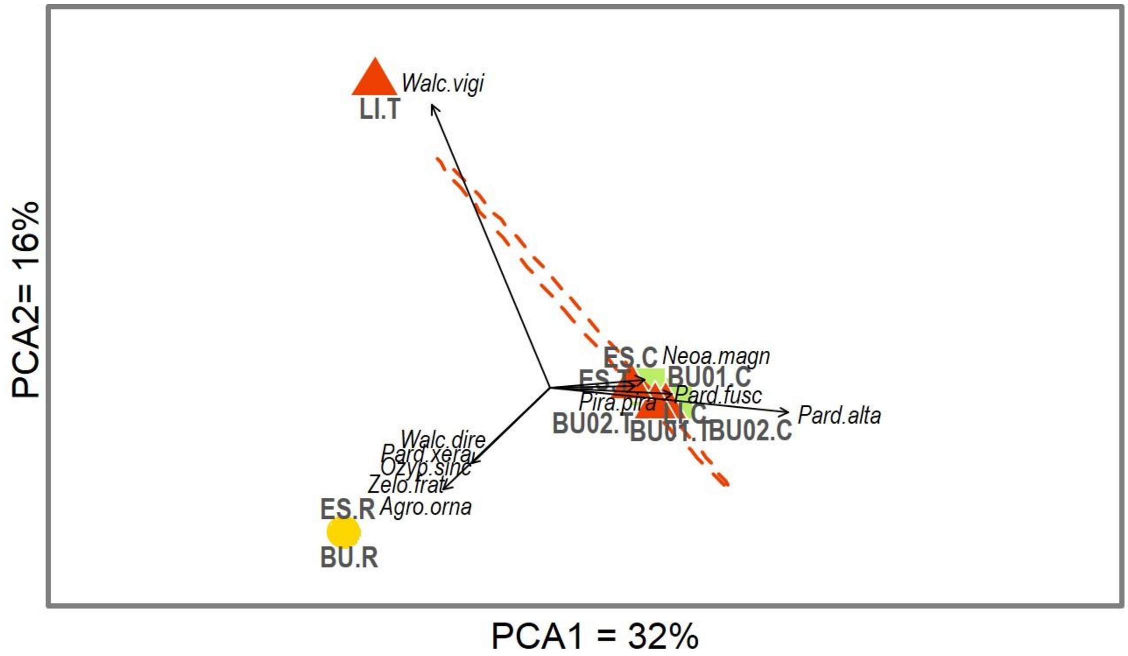

Figure 5-10: Principal Components Analysis (PCA) ordination of Araneae species assemblages collected in pitfall traps in 2016, showing relationships among treatments and sites. Abundance was standardized by trap effort and distances were computed with the Hellinger distance measure. Confidence ellipses (90% CI) are overlaid for differences in treatments: treatment (orange, T) and control (green, C) plots, which were distinct from reference communities (yellow, R). Labels are staggered slightly if plotted in the same location. Species vectors are overlaid for select species to assess the direction and strength of association with each site and treatment. Site codes: BU= Burton, ES= Edgewood South, LI= Lower Inonoaklin; Species codes: *Agro.orna= Agroeca ornata, Neoa.magn= Neoantistea magna, Ozyp.sinc= Ozyptila sincera , Pard.alta= Pardosa altamontis, Pard.fusc= P. fuscula, Pard. xera= P. xerampelina, Pira.pira= Pirata piraticus, Walc.dire= Walckenaeria directa, Walc.vigi= W. vigilax, Zelo.frat= Zelotes fratris*

Spider species assemblages from five monitoring years together show similar patterns to our single-year results, suggesting that additional years of monitoring will not reveal any differences in spider species composition between revegetation treatments and controls (Figure 5-11). Spider assemblages were structured in two broad groups: one of drawdown zone, control, and treatments, and one of upland reference areas (Figure 5-12). Assemblages were also more similar between certain sites than others (Figure 5-12; Table 5-3). Indicator analyses (constrained by results of the MRT) revealed more spider species characteristic of upland forest (reference) habitats than reservoir C, T, or DDZ habitats (Table 5-3).

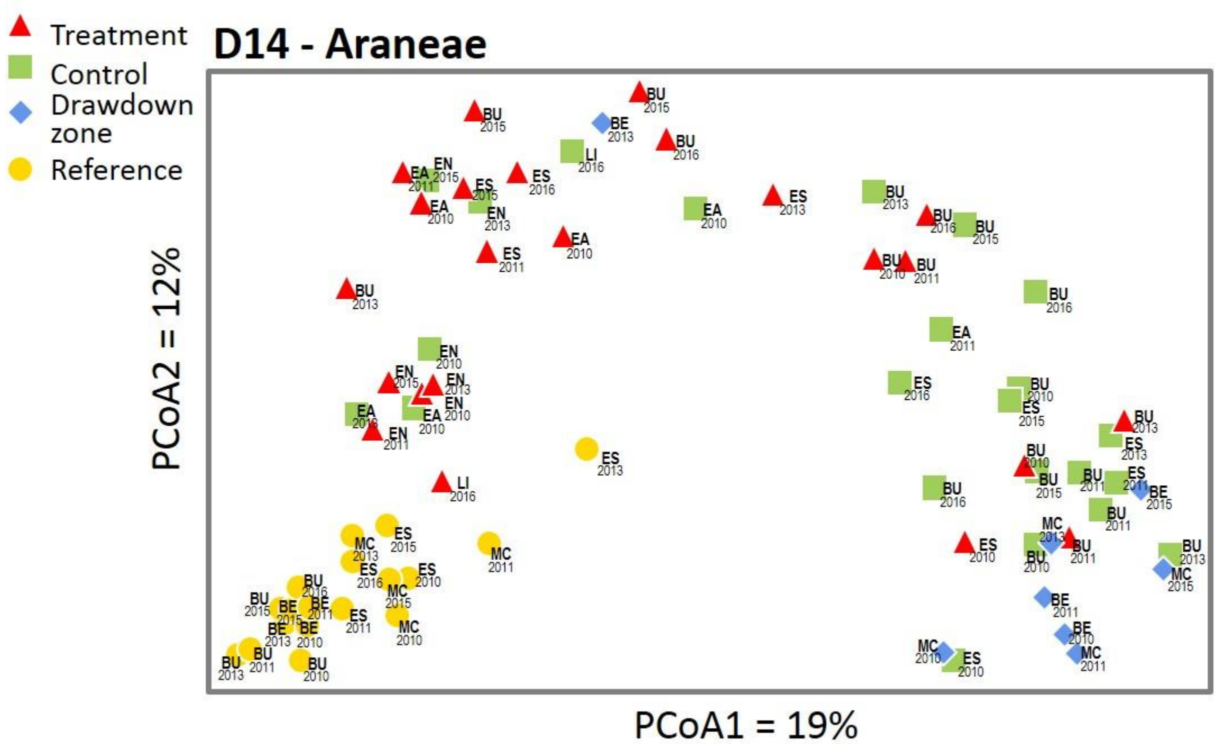

Figure 5-11: Principal Coordinates Analysis (PCoA) ordination of spider species (Araneae), showing relationships among treatments and sites in each year of sampling (2010, 2011, 2013, 2015, 2016). Distances computed with the Bray-Curtis distance (D14; same weight for rare and abundant species); per cent explained by each axis is given. Note: abundance was not standardized for trap effort differences between years and sites

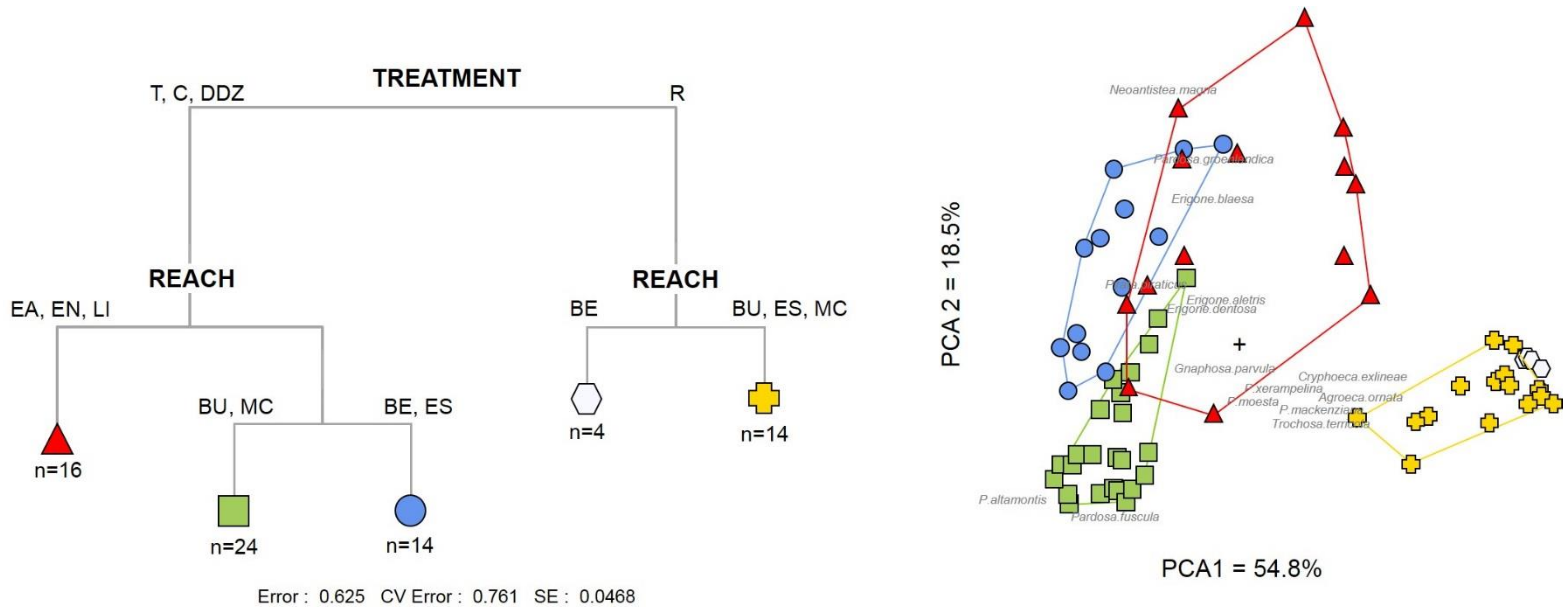

Figure 5-12: Multivariate regression tree (left, MRT) and corresponding Principal Components Analysis ordination (right, PCA) based on Hellinger distance depicting spider species assemblages among treatments and sites (for all years; excluding species present in ≤ 2 samples). The tree was selected based on 500 cross-validations and explains 37.5% of the variation in spider species composition. Symbols and colors correspond between the MRT and PCA (not the treatments depicted in other figures). Select taxa (those most distant from plot origin, +) were plotted on the ordination for clarity. Note: abundance was not standardized for trap effort. C= control, T= revegetation treatment, DDZ= drawdown zone, R= reference; BU= Burton, ES= Edgewood South, EN= Edgewood North, EA= East Arrow Park, BE= Beaton Arm, MC= Mosquito Creek, LI= Lower Inonoaklin

Table 5-3: Spider species indicative of each group in the MRT analysis shown in Figure 5-12. The results of Monte Carlo permutation tests show each indicator value (IndVal) that differed significantly from random (α = 0.05) after 9999 permutations. Results with significant IndVal >0.5 (bold) are species with strong associations for the group given by each node. Symbols correspond to samples shown in the MRT and PCA above

Node	Group	Indicator Species	IndVal	p-value
1	**Treatment:** T, C, DDZ **Reach:** EA, EN, LI	*Erigone blaesa*	0.304	0.029
2	**Treatment:** T, C, DDZ **Reach:** BU, MC	*Pardosa altamontis*	0.433	0.001
		Pardosa fuscula	0.405	0.01
		Oedothorax alascensis	0.281	0.037
3	**Treatment:** T, C, DDZ **Reach:** BE, ES	*Neoantistea magna*	**0.696**	**0.001**
		Pirata piraticus	**0.531**	**0.001**
		Praestigia kulczynskii	0.252	0.025
4	**Treatment:** R **Reach:** BE	*Cryphoeca exlineae*	**0.847**	**0.001**
		Tenuiphantes zelatus	**0.733**	**0.001**
		Walckenaeria cornuella	**0.727**	**0.001**
		Xysticus pretiosus	**0.652**	**0.003**
		Oreonetides filicatus	0.452	0.005
		Ceratinella brunnea	0.397	0.01
		Agelenopsis utahana	0.392	0.007
5	**Treatment:** R **Reach:** BU, ES, MC	*Ozyptila sincera*	**0.699**	**0.001**
		Agroeca ornata	**0.65**	**0.002**
		Pardosa mackenziana	0.438	0.007
		Robertus vigerens	0.429	0.002
		Cicurina idahoana	0.411	0.006
		Xysticus elegans	0.357	0.023
		Euryopis argentea	0.349	0.022
		Walckenaeria exigua	0.34	0.017
		Phrurotimpus borealis	0.332	0.016
		Pardosa xerampelina	0.313	0.038
		Pardosa dorsuncata	0.263	0.024
		Clubiona kastoni	0.245	0.047
		Walckenaeria directa	0.237	0.039
		Cybaeopsis wabritaska	0.214	0.019
		Xysticus montanensis	0.214	0.022
		Antrodiaetus cerberus	0.188	0.024
		Cybaeus morosus	0.166	0.031

Consistent with the results above, the overall test of concordance was significant ($W = 0.0514$, F= 3.25, $p < 0.001$), with spider species partitioning into two groups according to K-means. The two groups were segregated along the X-axis of the PCA diagram (Figure 5-13) and were comprised of species associated with reference sites (W= 0.274, F= 1.02, p= 0.0001) and species associated with sites in the drawdown zone (whether treated or not; W= 0.0914, F= 3.2, p= 0.0001). Several species were significantly concordant in the drawdown zone group and upland reference group (α= 0.1; Table 5-4).

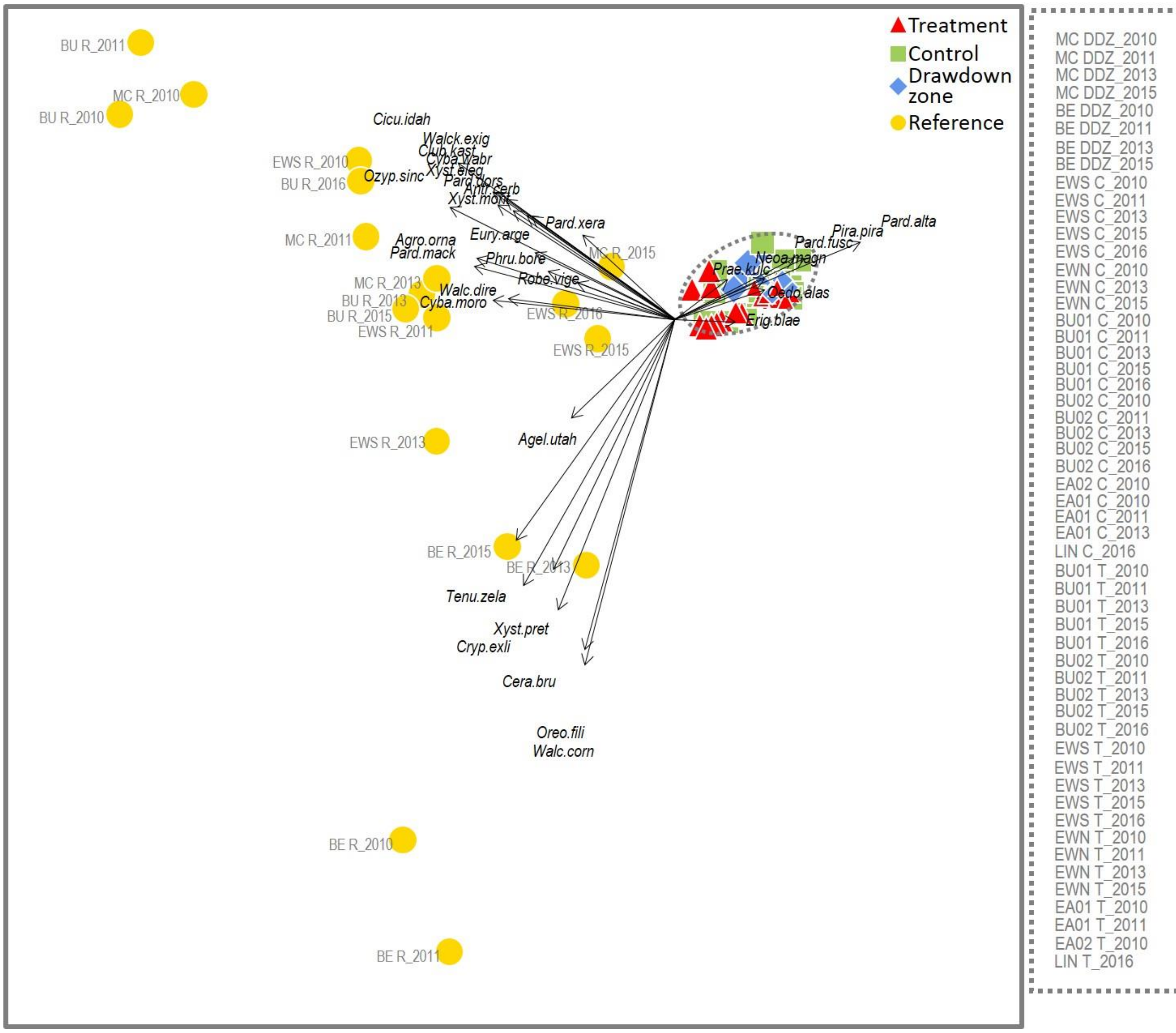

Figure 5-13: Principal Components Analysis (PCA) ordination with the partition results by Kendall Concordance Analysis for spider species in all sites, treatments, and years. Spider species assemblages formed two groups: upland reference (yellow) and one group including the drawdown zone, control and treatment plots (grey dashed outline). Sites overlapped largely within the drawdown zone group, thus labels are provided in the margin. Black vectors represent spider species abundance (uncorrected for sampling effort; species codes in Table 9-3). Both Malaise trap and pitfall trap data were pooled in this analysis. The horizontal axis explains 23 per cent of the variation in spider species assemblages. The vertical axis explains 12 per cent of the variation in spider species assemblages. Abbreviations for site: BU= Burton, BE= Beaton, EA= East Arrow Park, EN= Edgewood North, ES= Edgewood South, and MC= Mosquito Creek; and treatment: T= revegetation treatment, C= control, DDZ= untreated drawdown zone control, and R= upland reference. Overlapping points plotted with slight offset

Table 5-4: Spider species concordant with groups resolved by Kendall (W) Concordance Analysis. Only species occurring in more than two sites (site: treatment: year) were used in analyses. Species significant at α= 0.1 are shown

Group	Species Code
1) Treatment, Control, Drawdown zone	Call.plut*, Merm.tril**, Pard.moes**, Pard.alta***, Pard.fusc****, Pira.pira**, Xyst.fero**, Zelo.fratr*
2) Upland Reference	Agel.utah**, Agro.orna****, Antr.cerb**, Bath.pall**, Cera.brun***, Cicu.idah****, Club.kast**, Cryp.exli**, Cyba.wabr***, Cyba.moro***, Eury.arge**, Mica.puli**, Oreo.fili*, Ozyp.sinc****, Pard.dors**, Pard.mack**, Pard.xera**, Phru.bore**, Robe.vige**, Tenu.zela***, Troc.terr****, Walc.corn**, Walc.dire**, Walc.exig**, Xyst.eleg***, Xyst.mont,** Xyst.pret**

* p< 0.1, ** p<0.05, ***p<0.001, ****p<0.0001

5.4 Breeding Songbirds

Songbirds were surveyed between June 18 and July 18, 2016. A total of 107 variable radius point counts were sampled (Table 5-5; Appendix B). This is similar to previous years (which ranged from 91 to 123 point counts). Most point counts were visited twice; some could only be visited once due to high water elevations. Point counts that were visited twice were surveyed once in June and once in July, to record locally breeding bird species and capture within-year variability in species presence and detections. Survey effort varied by site, with the number of point counts established per site based on the amount of area available for sampling (as constrained by reservoir elevation). The highest number of point counts sampled in 2016 was in Burton Creek. Revegetation treatments were not applied at either Mosquito Creek or Beaton Arm, therefore point counts were established only in drawdown zone and reference (upland) habitat types at those locations.

Table 5-5: Number of point counts sampled per site, and type of treatment in 2016. Sites are ordered from south to north in the Arrow Lakes Reservoir

Site	Control	Treatment	Drawdown Zone	Reference	*Total*
Beaton Arm			4	9	*13*
East Arrow	4	5	2	7	*18*
Burton Creek	6	6	4	9	*25*
Edgewood North	2	4	2	4	*12*
Edgewood South	3	3		6	*12*
Lower Inonoaklin		8	1		*9*
Mosquito Creek			9	9	*18*
Total	*15*	*26*	*22*	*44*	*107*

A total of 1,819 observations of 89 species were recorded in 2016 (Table 5-6). As one observation might consist of multiple individuals, the actual number of individuals is higher (2,830 individuals). The lower number of species/observations in 2016 (and 2015) relative to previous years is due to a combination of factors including the later period of sampling which may exclude detections of certain species recorded only as migrants, and the fewer point count visits (2 visits vs. 3 in earlier years). Annual variation in songbird abundance may also contribute to these differences. These data indicate the suite of breeding species within each site, and the study area as whole. Across all six survey-years spanning the period from 2009 to 2016 (bird surveys were not completed on an annual basis), a total of 151 species have been detected during point count surveys, representing 12,219 observations.

Table 5-6: Total number of point count stations, visits, and bird detections recorded during five years of sampling under CLBMON-11B1

Year	Total PC Stations	Total PC Visits	Total Species	Total Observations	Total Individuals
2016	107	197	89	1,819	2,830
2015	91	176	79	1,474	1,868
2013	123	294	102	2,837	4,203
2011	117	342	121	3,297	5,021
2010	107	412	116	2,046	3,793
2009	106	179	79	791	1,013

Songbirds are the focal taxa for this survey type, and were represented by 53 species in 2016. In addition, there were 4 species of swift and hummingbird detected (Table 5-7). The remaining species were distributed among groups such as diurnal raptors, shorebirds and gulls, waterfowl, and woodpeckers. The number of songbird, swift and hummingbird species documented per site varied from 28 at Edgewood North to 39 at Mosquito Creek (Table 5-7).

Multiple species recorded from the study area during bird surveys are of conservation concern at the provincial and/or national level. Five COSEWIC listed species were encountered in 2016: Western Grebe (Special Concern), Barn Swallow, Bank Swallow, and Olive-sided Flycatcher (all Threatened), and Black Swift (Endangered). In prior survey years there have been observations of three other COSEWIC listed species: Horned Grebe and Long-billed Curlew (both Special Concern), and Common Nighthawk (Threatened). Five of the eight COSEWIC-listed species we have detected are aerial insectivores; a foraging guild which has experienced large declines of many species across varied taxonomic groups. Observations of provincially-listed species in 2016 include the blue-listed Barn Swallow, Black Swift, California Gull, Double-crested Cormorant, Great Blue Heron, and Olive-sided Flycatcher. Western Grebe was the only red-listed species detected. During previous years we have also recorded the blue-listed Caspian Tern and Long-billed Curlew.

Table 5-7: Total number of species observed and detections per bird group per study area in 2016 and all survey years combined. BE: Beaton Arm; EA: East Arrow; BU: Burton Creek; EN: Edgewood North; ES: Edgewood South; MC: Mosquito Creek. Spp: Species; Obs: Number of observations. Blanks indicate no observations

	BE		EA		BU		EN		ES		LI		MC		Total	
Bird Group	Spp	Obs	Spp	Obs	Spp	Obs	Spp	Obs	Spp	Obs	Spp	Obs	Spp	Obs	Spp	Obs
Waterfowl																
2016	2	5	5	16	4	12	2	2	1	1	8	14	3	7	10	57
All Years	10	53	12	153	12	92	12	55	9	21	15	71	8	101	20	546
Upland Game Birds																
2016	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
All Years	1	19	1	9	1	22	1	5	.	.	.	.	1	16	1	71
Grebes																
2016	.	.	.	.	.	.	1	1	.	.	1	3	.	.	2	4
All Years	1	1	.	.	1	1	2	10	1	3	2	4	.	.	4	19
Pigeons and Doves																
2016	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
All Years	.	.	2	4	2	3	1	4	1	1	.	.	.	.	2	12
Nighthawks and Nightjars																
2016	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
All Years	.	.	.	.	1	1	.	.	.	.	.	.	.	.	1	1
Swifts and Hummingbirds																
2016	2	2	1	5	1	1	.	.	1	1	1	1	1	1	4	11
All Years	3	28	3	40	4	22	4	12	3	30	2	3	3	8	4	143
Shorebirds, Gulls, Auks and Allies																
2016	1	2	2	15	3	22	4	21	2	9	1	1	1	3	6	83
All Years	4	25	7	83	6	115	7	93	5	53	3	86	6	83	16	538
Loons																
2016	.	.	1	2	1	7	1	7	1	3	.	.	.	.	1	19
All Years	1	6	1	13	2	24	1	15	1	10	1	5	1	5	2	78
Cormorants and Allies																
2016	.	.	.	.	.	.	.	.	.	.	1	1	.	.	1	1
All Years	.	.	.	.	.	.	.	.	.	.	1	1	.	.	1	1
Herons, Ibises and Allies																
2016	1	2	1	5	1	2	.	.	.	.	1	6	.	.	1	15
All Years	1	4	1	5	1	2	.	.	.	.	1	6	.	.	1	17
Vultures																
2016	.	.	.	.	1	1	.	.	1	4	.	.	.	.	1	5
All Years	.	.	1	2	1	9	1	3	1	7	.	.	.	.	1	21
Hawks, Eagles and Allies																
2016	1	2	1	6	2	8	2	3	2	5	1	6	3	1	3	41
All Years	2	18	4	35	5	67	3	18	3	52	3	17	4	47	6	254
Owls																
2016	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
All Years	.	.	.	.	.	.	1	1	.	.	.	.	.	.	1	1
Kingfishers and Allies																
2016	1	1	.	.	.	.	.	.	.	.	1	1	1	1	1	3
All Years	1	7	1	5	1	6	1	2	1	7	1	5	1	7	1	39
Woodpeckers and Allies																
2016	2	7	3	6	2	2	4	12	2	2	2	8	4	25	4	62
All Years	5	93	5	93	5	54	4	31	6	48	3	30	5	108	7	457
Falcons and Allies																
2016	.	.	2	6	1	1	.	.	.	.	.	.	.	.	2	7
All Years	.	.	2	19	2	12	1	6	2	8	1	2	1	1	2	48
Songbirds																
2016	29	163	31	268	34	273	28	160	36	185	29	162	38	300	53	1511
All Years	55	1400	62	2253	63	1821	53	1000	58	1071	50	676	60	1752	81	9973
Total Species and Detections																
2016	**39**	**184**	**47**	**329**	**50**	**329**	**42**	**206**	**46**	**210**	**46**	**203**	**51**	**338**	**89**	**1819**
All Years	**84**	**1654**	**102**	**2714**	**107**	**2251**	**92**	**1255**	**91**	**1311**	**83**	**906**	**90**	**2128**	**151**	**12219**

A total of 1,522 observations of 57 species of songbird, swift, and hummingbird were made in 2016. Applying the selection criteria outlined in Hawkes et al. (2010) to the bird data collected in 2016 resulted in the following datasets:

1. Birds within 75 m of the point count centre: 545 observations of 50 species
2. Birds documented within 30 m of the point count centre: 153 observations of 38 species

5.4.1 Species abundance and diversity – 2009 to 2016

Differences in relative abundance (the number of bird observations per point count per visit; CPUE) were significant among habitat types (*F*=35.1, *p*=0.0001), and among years (*F*=2.3, *p*=0.043; Figure 5-14). Differences were significant among sites also when comparing only control (*F*=7.7, *p*=0.003) or only treatment plots (*F*=4.57, *p*=0.015), but there was no significant difference in abundance among sites for reference plots. Differences among sites reflects the differences in habitat components, structure, and flooding regimes of these discrete areas along the reservoir. Natural inter-annual variation associated with the presence and abundance of songbirds in a given area due to weather or other environmental conditions and inter-annual variation in reservoir levels/operations is also expected.

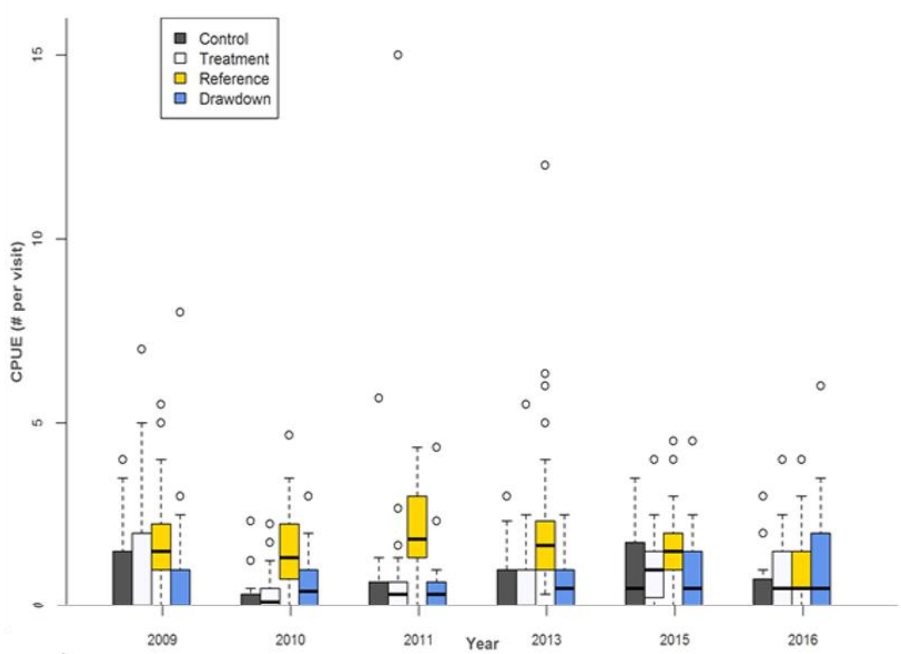

Figure 5-14: Variation in standardized abundance (number of individuals per point count per visit) among habitat types and years (sites were pooled).

Differences in corrected species richness (the number of species per point count per visit) were significant among habitat types when all habitat types were tested (*F*=79.5, *p*=0.0001) and among years (*F*=4.7, *p*=0.0003; Figure 5-15 and Figure 5-16). Differences were also significant among sites and years when comparing only a single habitat type (e.g., significant differences in richness exist within control plots from different sites). Interactions between site and year were significant when comparing only control plots (*F*=2.0, *p*=0.08) and only reference plots (*F*=1.7, *p*=0.093).

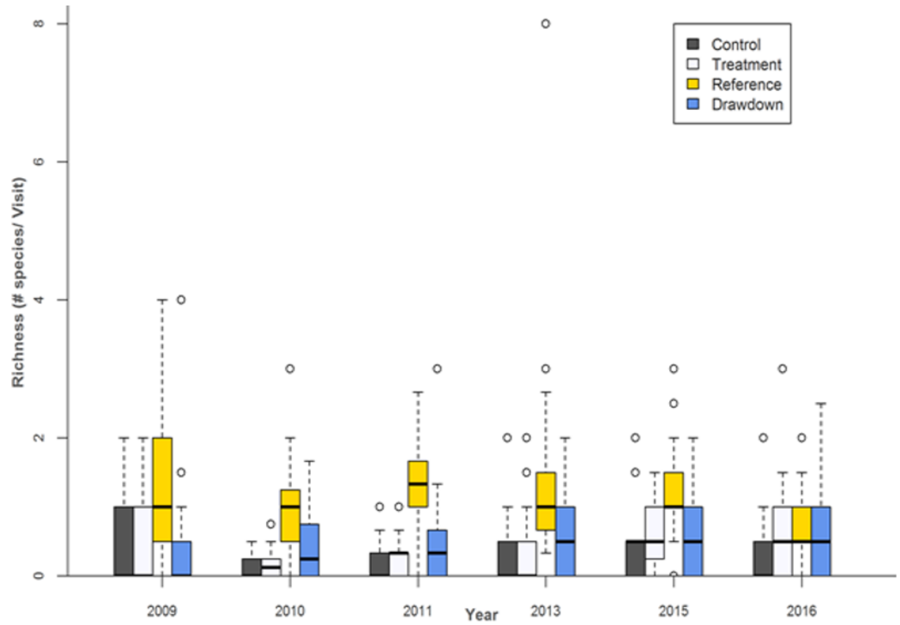

Figure 5-15: Variation in standardized species richness (number of species per point count per visit) among habitat types and years (sites were pooled).

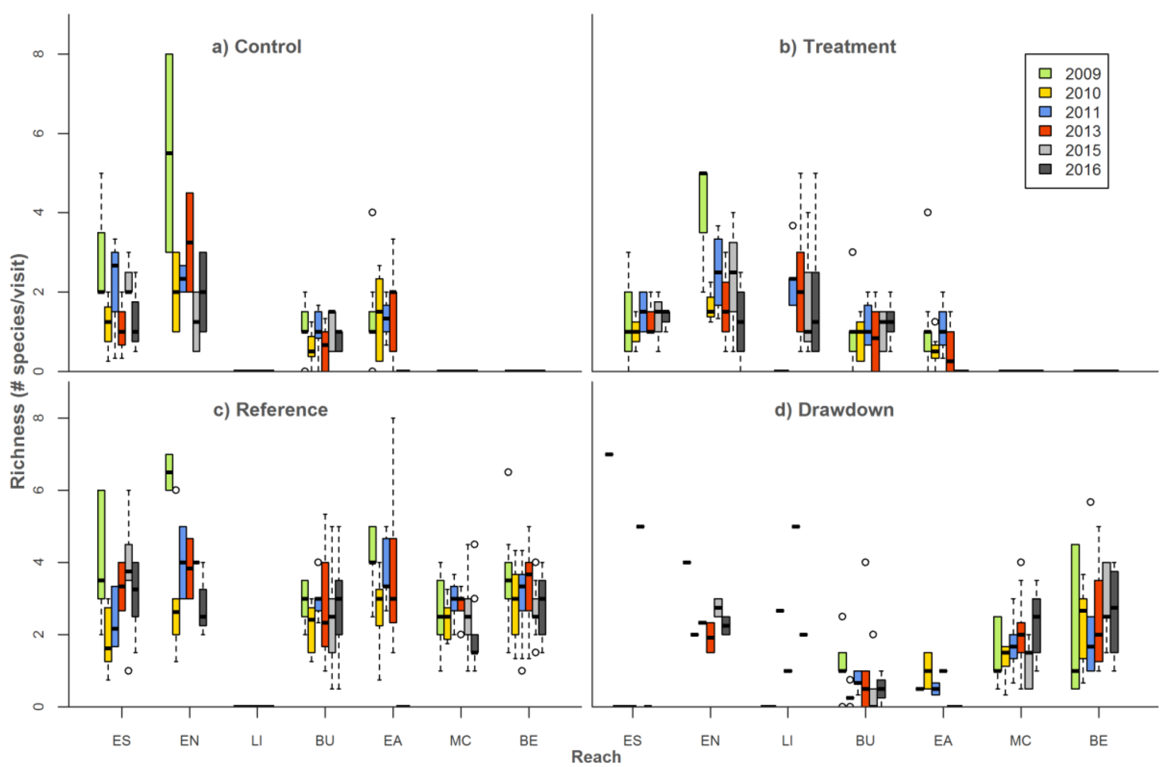

Figure 5-16: Variation in songbird species richness (number of species per point count per visit) in Arrow Lakes Reservoir by habitat type: a) control, b) treatment, c) reference, and d) drawdown zone

Species diversity is similar to richness, though it accounts for both the abundance and evenness of the species present. Differences in species diversity (Shannon's H) were found to be significant both among habitat types (*F*=115.2, *p*=0.0001) and years (*F*=8.3, *p*=0.0001) (Figure 5-17). Interactions were not significant.

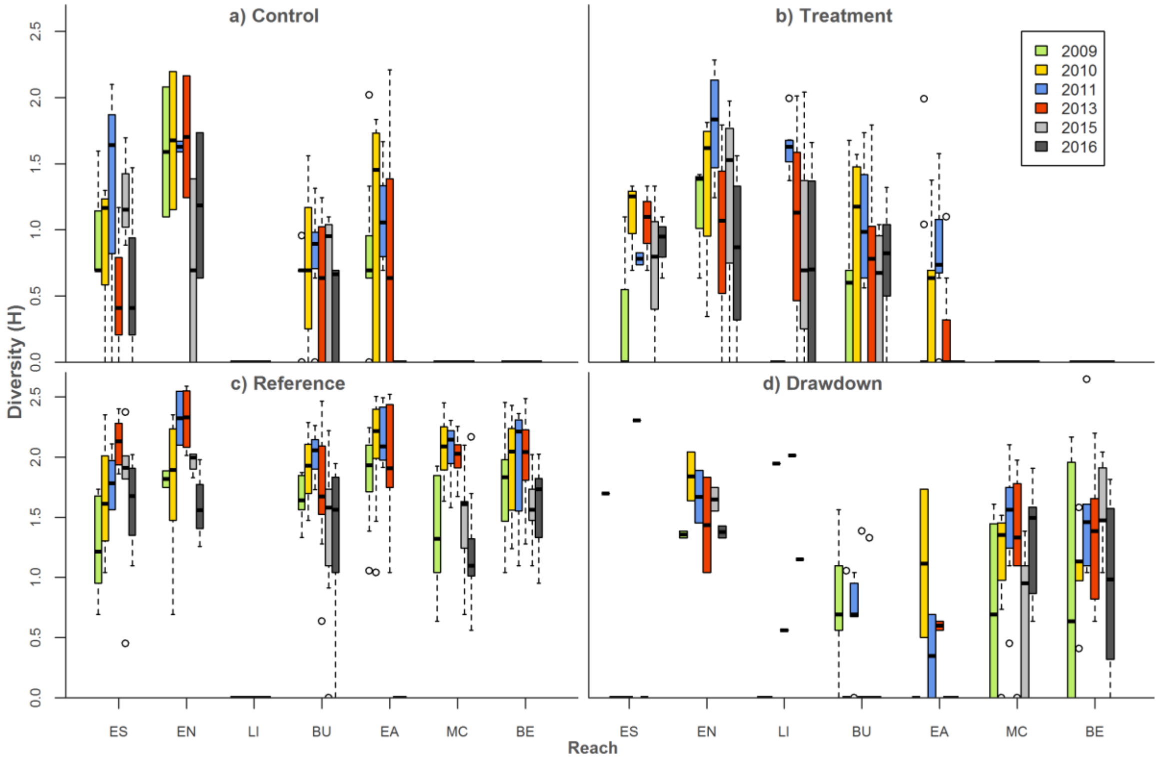

Figure 5-17: Variation in diversity (H) in point counts over time in the different sites of Arrow Lakes Reservoir in a) control sites, b) treatment sites, c) reference sites, and d) drawdown zone sites

When comparing only songbird data from within 30 m of the point count centre, a similar trend emerges. With this constrained data, there is still a significant effect of treatment (*F*=51.4, *p*=0.0001) and year (*F=2.5*, *p*=0.027) on richness, and treatment (*F*=51.4, *p*=0.0001) (but not year) on abundance (Figure 5-14). Shannon's diversity (H) also differed significantly among habitat types (*F=85*, *p*=0.0001), but there was no significant year effect (Figure 5-18).

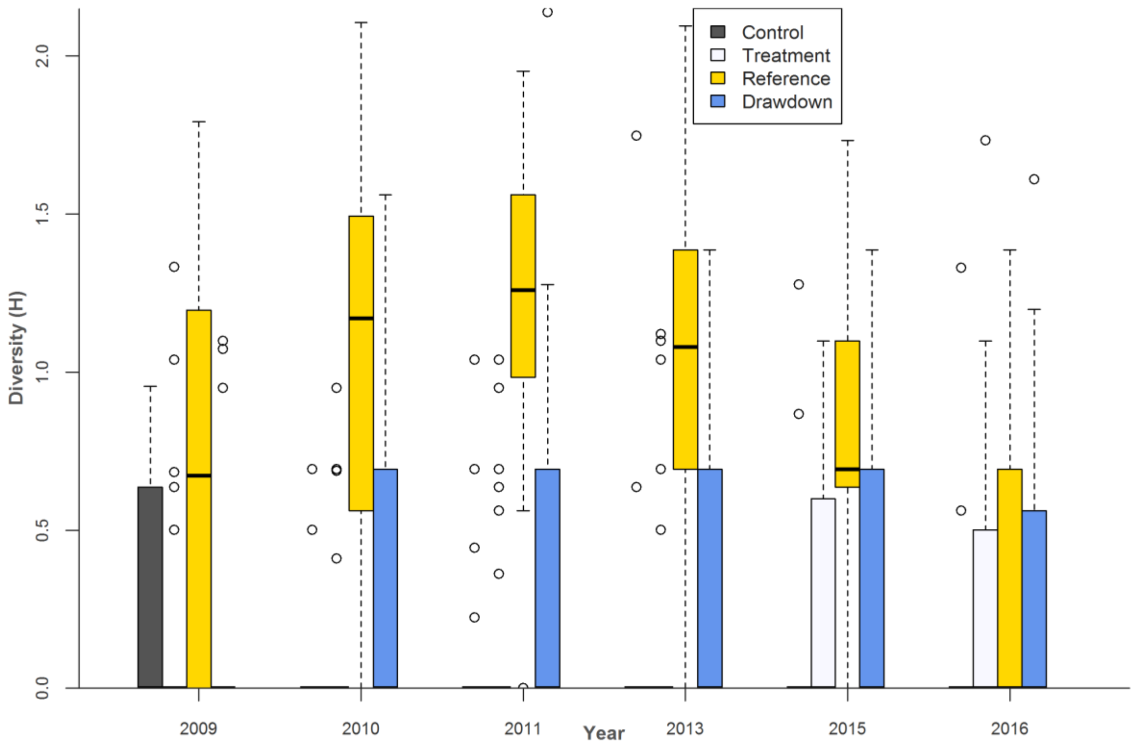

Figure 5-18: Variation in species diversity (H) over time among treatment types in the Arrow Lakes Reservoir (all sites pooled)

5.4.2 Species abundance and diversity – 2016

Treatment-level effects on the constrained dataset could not be investigated for all habitat types at all sites in 2016 alone owing to the low number of replicates. There was enough information to statistically test habitat and site effects for Burton Creek, Edgewood North, and Edgewood South for control and treatment habitats only. With these constraints, there were no significant habitat or site effects on abundance, richness, or diversity.

5.4.3 Songbird species composition and similarity

Songbird communities were structured similarly under both coefficients, which suggests that differences in species abundances did not drive the overall compositional differences (Figure 5-19). Reference habitats from most sites grouped together (though not tightly), indicating that they shared more bird species than with the drawdown zone of their own site. Songbird communities were quite similar between control plots of Burton and Edgewood South, the drawdown zones of Edgewood North and Lower Inonoaklin, and the treatment plot of Edgewood South (especially for D17 resemblance coefficient). These areas appear to have a somewhat distinct species assemblage compared to the other sites and plots.

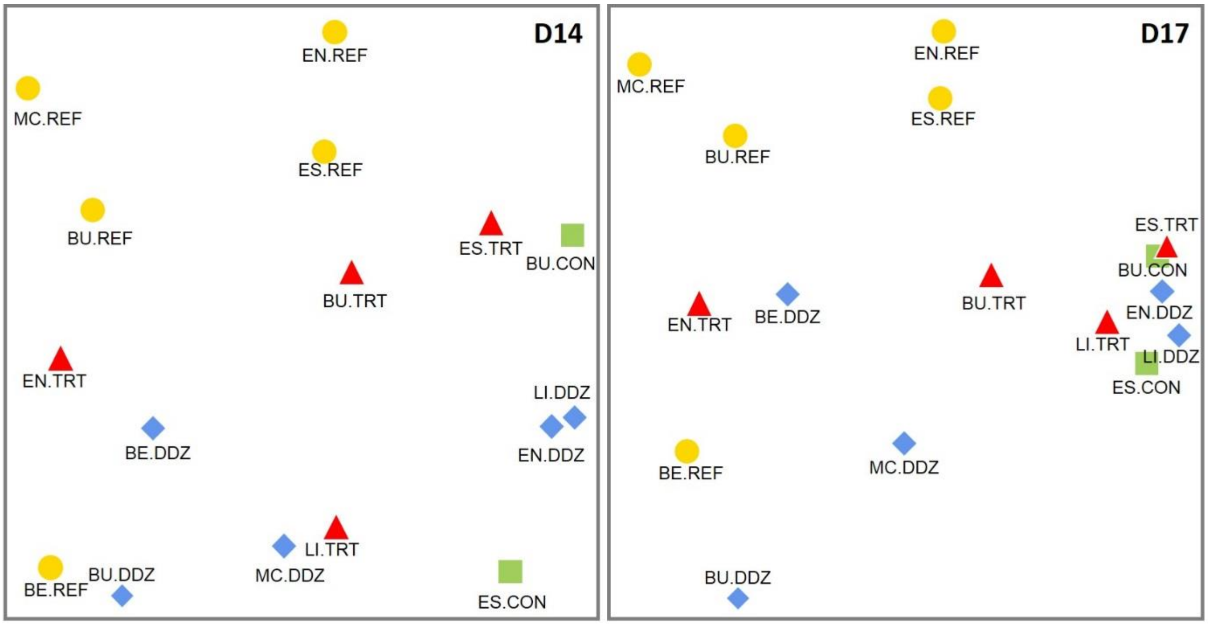

Figure 5-19: Principal Coordinate Analysis (PCoA) ordination diagram representing songbird community similarity for each site and treatment as computed by the Bray-Curtis distance (D14; left) and the Hellinger-Euclidian distance (D17; right). Colors refer to treatment [green: control (CON), blue: drawdown zone (DDZ), red: treated (TRE), yellow: reference (REF)]. Two-letter prefix refers to site: BE = Beaton Arm; BU = Burton Creek; EN = Edgewood North; ES = Edgewood South; LI = Lower Inonoaklin; MC = Mosquito Creek

As in previous years, songbird species appear to mainly split in two groups according to K-Means partitioning and PCA, though the split was not as clean as in previous years. The overall test of independence associated with Kendall's coefficient of concordance (W) showed that several songbird species were concordant (W=0.079, F=1.9, p=0.0215). Although the partition did not appear very strong in 2016, at least some of the species within each group were concordant with each other, and seem to represent specific treatment and sites, although less clearly than in previous years (group 1: W=0.145, F=1.5, p=0.0985; group 2: W=0.27, F=4.4, p=0.0001). Group 1 consists of species mostly found in the drawdown zone (especially American Robin [AMRO]), and in control, drawdown, and treated sites (Yellow-rumped Warbler [YRWA]). Group 2 is composed of species associated with the reference zones (Figure 5-20). After correction for multiple testing, no species were still significantly concordant in group 1 (at α< 0.1), but two species were concordant with each other in group 2 (Golden-crowned Kinglet [GCKI] and Hammond's Flycatcher [HAFL]). Species significantly concordant before correction for multiple testing were included in the PCA.

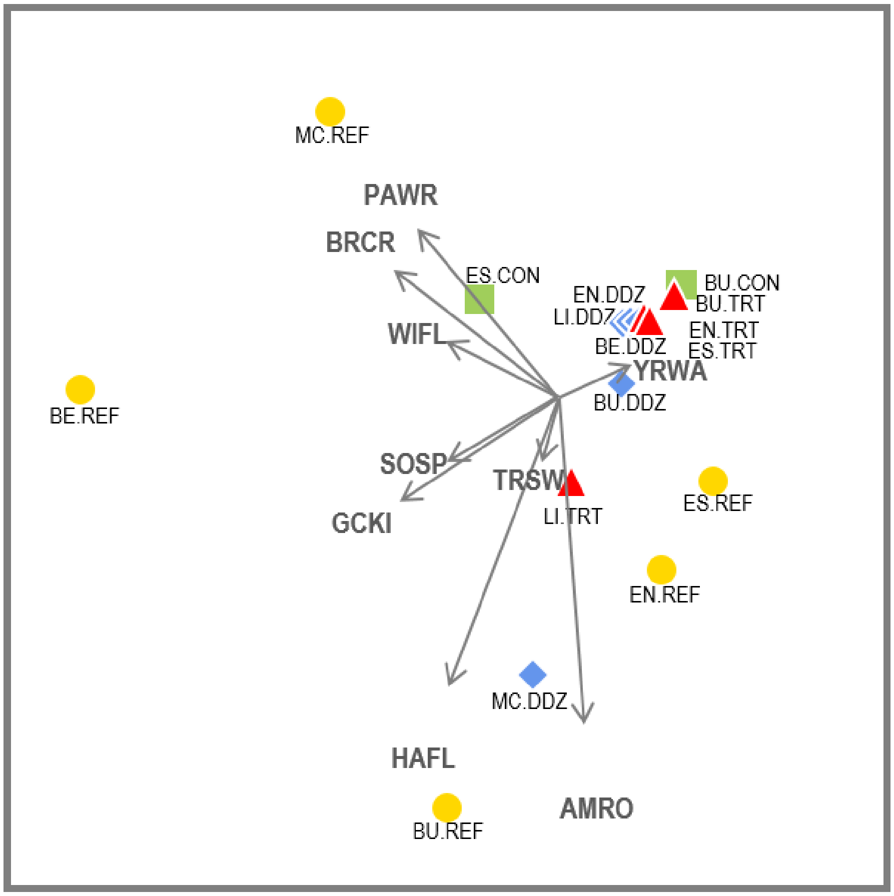

Figure 5-20: Principal Components Analysis (PCA) ordination diagram with the partition of results by K-Means. Grey vectors represent species. Colors refer to treatment [green: control (CON), blue: drawdown zone (DDZ), red: treated (TRE), yellow: reference (REF)]. Two-letter prefix refers to site: BE = Beaton Arm; BU = Burton Creek; EN = Edgewood North; ES = Edgewood South; LI = Lower Inonoaklin; MC = Mosquito Creek. Overlapping points plotted with slight offset

Similar results were obtained by multivariate regression tree analyses, with a clear partition between species from the drawdown zone (drawdown, control, and treated sites), and species from the reference sites. Indicator species analysis based on these groupings found no indicator species for the drawdown zone (group 1), but three species were found to be statistically-indicative of the reference zone (group 2: Pine Siskin [*Indval*=0.73, *p*=0.012], Golden-crowned Kinglet [*Indval*=0.6, *p*=0.017], and American Robin [*Indval*=0.5, *p*=0.023]). These three species were also discriminant species for group 2, while group 1 had only one weakly discriminant species (Chipping Sparrow).

5.4.4 Songbird food habits

Many songbird species feed on arthropods, and the relationship between arthropod biomass and songbird communities is relatively well-understood (e.g., Holmes et al. 1979; McMartin 2000). Revegetating the drawdown zone of mid- and lower Arrow Lakes Reservoir is predicted to first affect arthropod communities (as measured by changes in biomass, species richness, and composition; see Section 5.3). These changes should be followed by a measureable change in either the songbird communities or the relative abundance of certain species associated with the two groups identified in Table 5-8.

Songbirds can be grouped by their feeding habits (Table 5-8). The relative abundance of each songbird feeding guild was correlated with one or more orders of arthropods sampled in 2016 (Figure 5-21). As in previous years, no apparent association between revegetation treatment and songbird food preference was observed (Figure 5-21; i.e., insectivorous birds were not strongly correlated with treatment sites). In addition, no one particular bird foraging-guild appears strongly correlated with any particular treatment. While no associations are obvious among sites within the drawdown zone, there is a separation between reference plots and plots within the drawdown zone.

Table 5-8: List of songbird species per food group[1] included for 2016. Data was constrained to the study sites and habitats sampled for both songbirds and arthropod biomass (Burton: T,C,R; Edgewood South: T,C,R; Lower Inonoaklin: T). Species in this table are the same as those depicted in Figure 5-21

Food Group	Species Code
Insectivores	AMRE, COYE, GCKI, MACW, MGNW, NAWA, REVI, TOWA, YEWA, YRWA
Aerial Insectivores	ALFL, DUFL, HAFL, NRWS, VGSW, WIFL
Insectivores and Seed eaters	BCCH, CHSP, DEJU, LZBU, RBNU, SAVS, SOSP
Insectivores and Frugivores	GRCA, SWTH
Insectivores and Nectarivores	RUHU
Omnivores	AMRO

[1] Food groups were determined from published literature, such as The Birds of North America Online

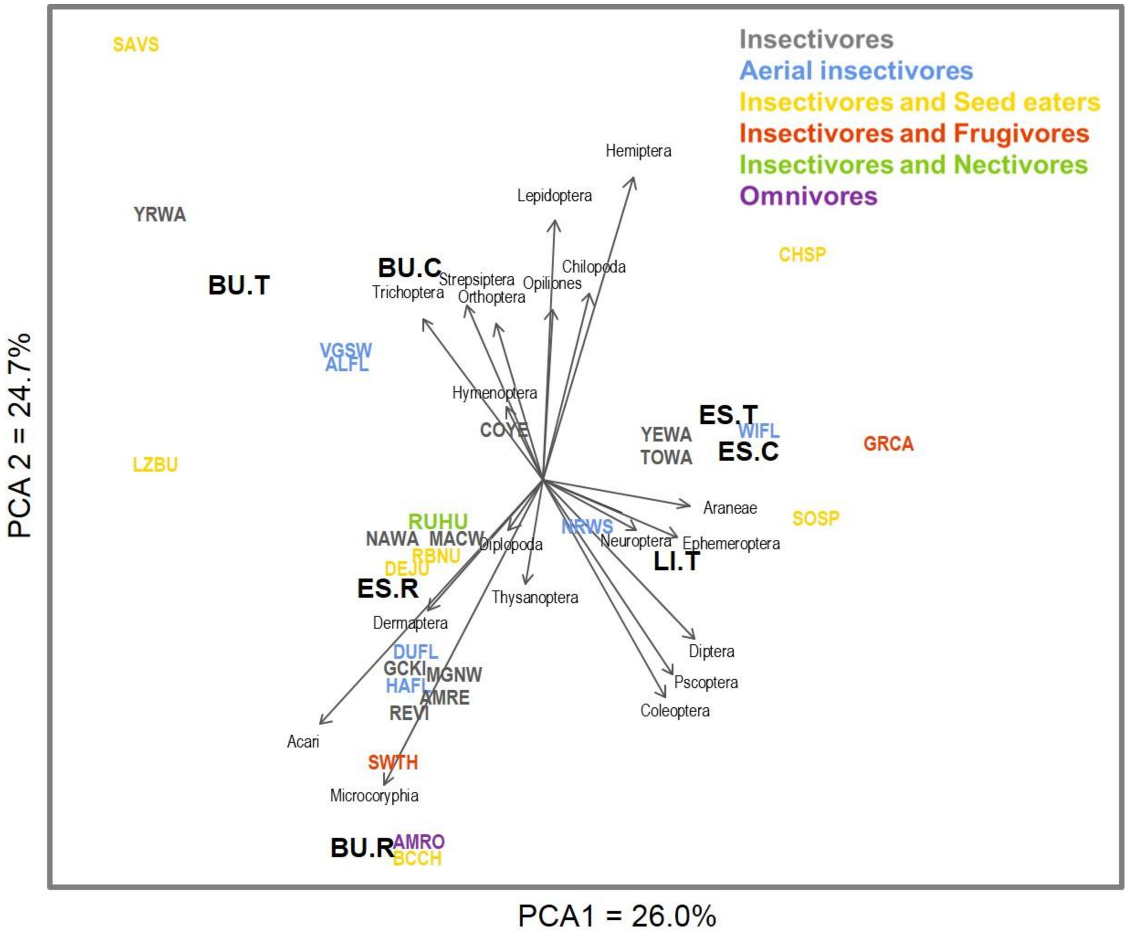

Figure 5-21: Principal Components Analysis (PCA) ordination of bird species (Hellinger distance) with biomass of arthropod orders for the 2016 monitoring year. Axis 1 explains 26.01% of the variation in bird species assemblages. Axis 2 explains a further 24.73%. Vectors are drawn to scale and direction with increasing biomass of each arthropod order. Four-letter bird species codes are provided for the centroids of each species on the ordination plot, colored according to food group defined in Table 5-8. Only a subset of sites were sampled for both songbirds and arthropod biomass, and thus, only three sites were included. T = treatment, C = control, R = reference; BU = Burton Creek, ES = Edgewood South, LI= Lower Inonoaklin

5.4.5 Nesting Evidence

Nest searches were completed within the drawdown zone and adjacent habitat (but not in upland reference habitat) at all sites. Plots were searched over the same date span as point count surveys, typically occurring after the point count period had ended for a given day. In total, eight nests of four species were located from Burton Creek, Mosquito Creek, and Lower Inonoaklin (Table 5-9). All nests located at Burton Creek and Mosquito Creek were ground-nests (Spotted Sandpiper and Savannah Sparrow), while both tree/shrub and ground-nests were found at Lower Inonoaklin (Spotted Sandpiper, Cedar Waxwing, Chipping Sparrow, and American Robin). The majority (5 of 8) of nests belonged to Spotted Sandpipers. Spotted Sandpiper is a commonly-occurring breeding bird throughout the drawdown zone of Arrow Lakes and Kinbasket reservoirs. There did not appear to be any discernible effect of treatment in the nesting site preference for this species, with two nests in the drawdown zone, one nest in control, and two nests in treated plots. The only other ground nest (Savannah Sparrow) was within a treated area. The remaining nests were from shrub and tree-nesting species, with a couple of these found within planted cottonwood at Lower Inonoaklin. Nests ranged from an elevation of 436 m to 443 m. In addition to the found nests, there were additional nesting evidence found, such as recently fledged birds or recent (built that year) but unoccupied nests.

Birds, even of the same species at the same site, may initiate nest building or egg laying at different times due to a variety of factors. Some birds may nest multiple times in a season, or may do so only if the first attempt failed, providing enough time to attempt a second brood before fall migration. The date that nests were found ranged from June 18th to July 28th, though nests were at a variety of stages when found. Of physical nests found, a total of four had unknown outcomes, due to eggs still in nest at the time of the last check, or a fledgling time that occurred between field sessions. One nest appears to have been abandoned after nest building (Cedar Waxwing), and one was found with an infertile or abandoned egg, but with recent fledglings nearby that may or may not have been associated with that same nest (Chipping Sparrow). Three other recently fledged nestlings were found (Nashville Warbler, Chipping Sparrow, and Savannah Sparrow), indicating successful nesting nearby. Remaining nests (all Spotted Sandpipers) had success or probable success in fledging young.

Table 5-9: Observations made during nest searching in 2016 surveys, including nest location and fate. Site: BU: Burton Creek; LI: Lower Inonoaklin; MC: Mosquito Creek. Treatment: DDZ: Drawdown zone (non-revegetated, non-designated plot); CON: Control (designated non-revegetated plot); TRT: Treatment (designated revegetated plot).

Nest	Species	Reach	Treatment	No. Eggs	Substrate	Height (m)	Success/Fail
	Chipping Sparrow	BU	DDZ	N/A	N/A	.	Fledglings (no nest found)
1	Savannah Sparrow	BU	TRT	5	Ground	0	Unknown
	Spotted Sandpiper	BU	DDZ	N/A	N/A	.	Fledglings (no nest found)
2	Spotted Sandpiper	BU	DDZ	4	Ground	0	Probable Success
3	Spotted Sandpiper	BU	TRT	4	Ground	0	Probable Success
4	Spotted Sandpiper	BU	CON	4	Ground	0	Probable Success
	American Robin	LI	TRT	.	Tree (cottonwood)	.	Unknown
5	Cedar Waxwing	LI	TRT	0	Tree (cottonwood)	3	Abandoned
6	Chipping Sparrow	LI	CON	1	Shrub (snowberry)	0.5	Unknown
	Common Yellowthroat	LI	N/A	N/A	N/A	.	Female carrying food (no nest found)
	Nashville Warbler	LI	TRT	N/A	N/A	.	Fledglings (no nest found)
7	Spotted Sandpiper	LI	TRT	4	Ground	0	Probable Success
8	Spotted Sandpiper	MC	DDZ	.	Ground	0	Success

This was the second season of nest-searching effort from the drawdown zone of Arrow Lakes Reservoir as part of this project. Nest data helps determine not only what species are present and their abundance (as gathered by point count data), but also if drawdown zones provide suitable nesting habitat for birds, and if so, what species. Results from this and last year's nest searching efforts indicate that drawdown zone areas are particularly utilized by Spotted Sandpiper. Shorebirds are not easily surveyed by point count methods, but are likely consistently present in the region across years. The presence of nests of in planted cottonwoods two years in a row is proof that at least some birds will utilize transplanted vegetation for nesting where suitable characteristics exist.

5.5 Bats

Bat detectors (*n*=14) sampled sites in Lower and Mid-Arrow Lakes for a combined total of 9,527 hours between May 6 and September 29, 2016 and recorded 207,242 bat calls. Of these, the Kaleidoscope software classified 192,252 (92.8%) as bats. All 12 bat species that could occur in the study area were classified by Kaleidoscope. All but one site (Box Lake) had at least one record of each of the 11 or 12 expected species of bat (Table 5-10).

Townsend's big-eared bat (COTO) and Northern Myotis (MYSE), both provincially blue-listed, were documented from every site sampled in 2016. Fringed Myotis (MYTH), also blue-listed in B.C., was documented from all sites except Box Lake. Western Small-footed Myotis (MYCI), which is blue-listed in the province, was documented from Edgewood South, the only site that was assessed for this species. Both federally endangered species (i.e., MYSE and Little Brown Myotis [MYLU]), were detected at all sites sampled (Table 5-10).

The most frequently classified species (57,085 files) was the California Myotis (MYCA), which also had the most classifications at five of eight sites sampled (Table 5-10). MYLU had nearly as many classified calls (57,005) and was the most frequently recorded species at the three remaining sites. COTO and MYTH were the most infrequently detected species with only 57 and 86 files assigned to each species.

Lower Inonoaklin was the busiest site in terms of the total number of detections, with just over 13,000 more recordings than the next most active site (Armstrong Lake). Conversely, Mosquito Creek was the site with the fewest detections overall.

Table 5-10: Bat species documented at each study site in Lower and Mid-Arrow Lakes Reservoir in 2016. "N/A" indicates a species was omitted from analysis for the site based on low probability of occurrence. Numbers in brackets provide the number of bat detector units sampling each site. See Table 4-2 for species codes and corresponding common names

Sites	Reach	COTO	EPFU	LACI	LANO	MYCA	MYCI	MYEV	MYLU	MYSE	MYTH	MYVO	MYYU	Total	No. Species
AL (1)	Armstrong Lake	1	624	1086	4030	8945	NA	85	10167	19	2	2444	861	28264	11
BA (1)	Beaton Arm	3	22	151	249	11253	NA	71	5679	15	2	2409	5131	24985	11
BC (3)	Burton Creek	2	149	1809	1677	9376	NA	53	7845	32	5	2003	1900	24851	11
BL (1)	Box Lake	3	105	2	295	4526	NA	48	1371	39	0	1674	2767	10830	10
ES (3)	Edgewood South	23	973	645	6537	3801	672	296	8750	165	31	2741	1015	25649	12
LI (2)	Lower Inonoaklin	15	989	2049	8631	10974	NA	483	8424	68	34	3661	5948	41276	11
MC (1)	Mosquito Crek	5	98	322	2069	2840	NA	29	1911	10	7	1052	1171	9514	11
WA (2)	West Arrow	5	1642	165	4161	5370	NA	174	12858	31	5	2253	222	26886	11
	Total Files	**57**	**4602**	**6229**	**27649**	**57085**	**672**	**1239**	**57005**	**379**	**86**	**18237**	**19015**	**192255**	**12**

The number of bat recordings per detector-hour (as a measure of relative abundance) was highest at Lower Inonoaklin, while Mosquito Creek had the lowest rate (Figure 5-22), which matches the results for total number of detections. Beaton Arm had the second highest detection rate despite having the third lowest number of total detections. The average detection rate for all sites combined was ~20.18 bat recordings per hour.

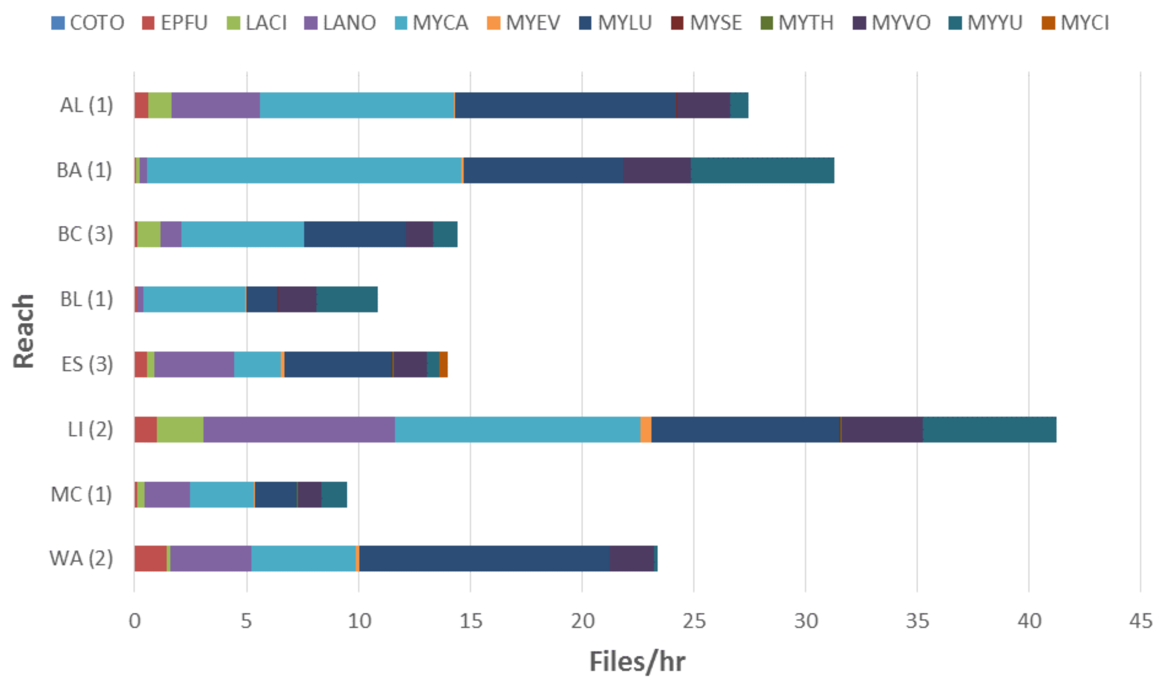

Figure 5-22: Relative abundance (recordings per detector hour) for all bat species at each site in the Lower and Mid-Arrow Lakes Reservoir, summer 2016

Data were pooled by site and the proportion of detections for each species was compared (Figure 5-23). The main pattern that emerges among sites is the prevalence of *Myotis* species compared to larger bat species (i.e., COTO, EPFU, LACI and LANO). Larger bat species combined averaged ~20% of the total number of detections, with a range of 1.7 (Beaton Arm) to 31.9% (Edgewood South). Beaton Arm and Box Lake (3.7%) had exceptionally low representation from larger bat species compared to other sites.

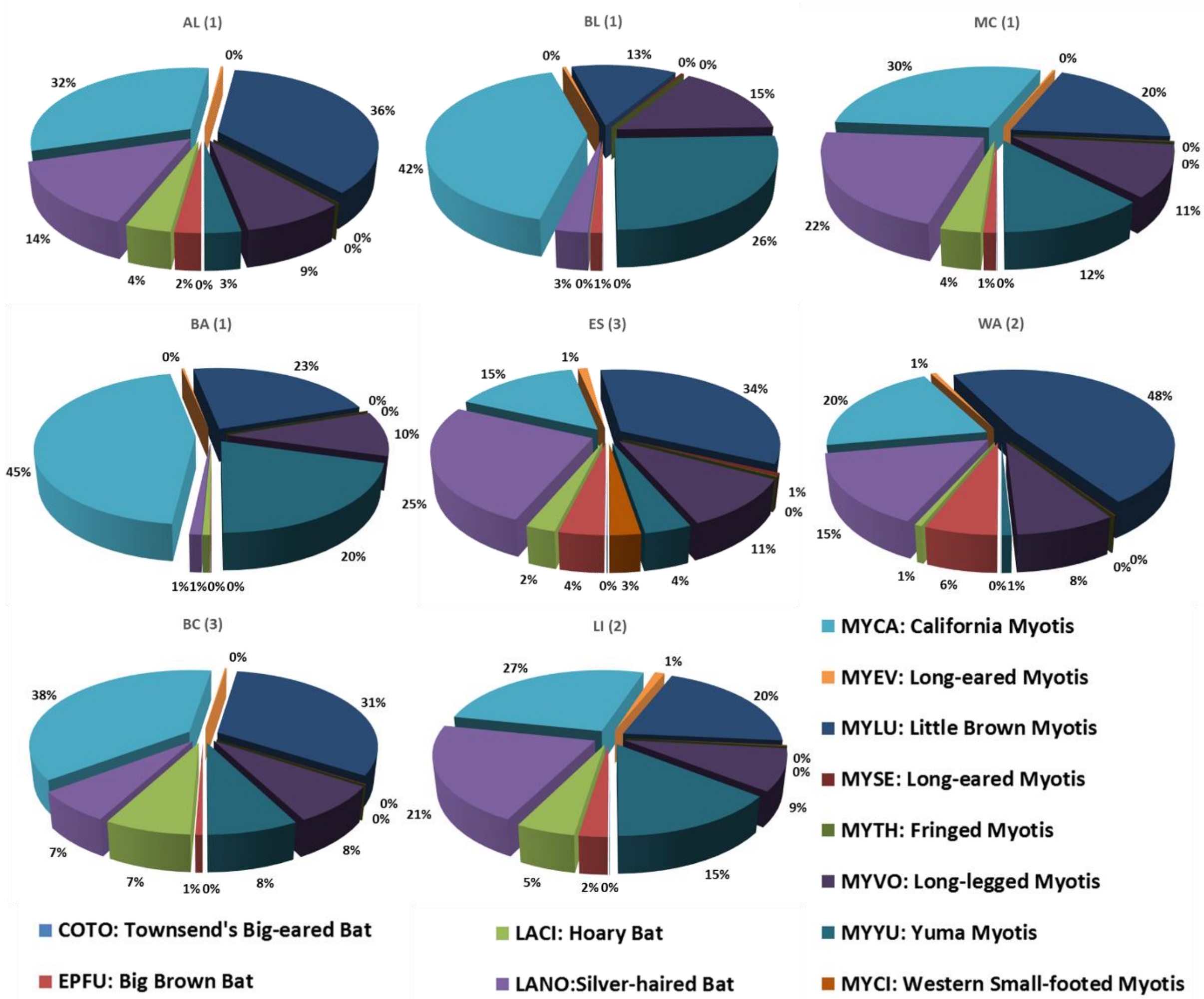

Figure 5-23: Proportion of files assigned to each of the 12 bat species documented from sites in 2016. Numbers in brackets provide the number of bat detector units sampling each site. Non-reservoir sites included: AL= Armstrong Lake, BL= Box Lake, WA= West Arrow. Reservoir sites included: BA= Beaton Arm, BC= Burton Creek, ES= Edgewood South, LI= Lower Inonoaklin, MC= Mosquito Creek.

The recording period was investigated to see when bats were most active relative to sunrise and sunset (Figure 5-24). Because SM2BAT+ units allow for a dynamic schedule that shifts with sunrise and sunset times, we calculated the relative abundance (files per hour) for the pre-sunset and post-sunrise half-hour blocks, along with five post-sunset and one pre-sunrise hour blocks. According to the 2016 data, there was a virtual absence of activity in the pre-sunset and post-sunrise periods. The detection rate increased after sunset and the peak of bat activity occurred in the second hour block after sunset, and was followed by a continual decrease in the number of recording per hour. The hour before sunrise had less bat activity than any of the post-sunset hour blocks. The *Myotis* species appeared to be consistent in their proportionate activity levels for each recording period. EPFU appeared to be most active in the two hours after sunset and hour before sunrise, while LACI continuously increased activity after sunrise and was most active in the fifth hour after sunset. LACI was not very active in the hour block before sunrise, so based on our sampling schedule we cannot determine whether their activity level continues to increase or starts to decrease after the fifth hour past sunset.

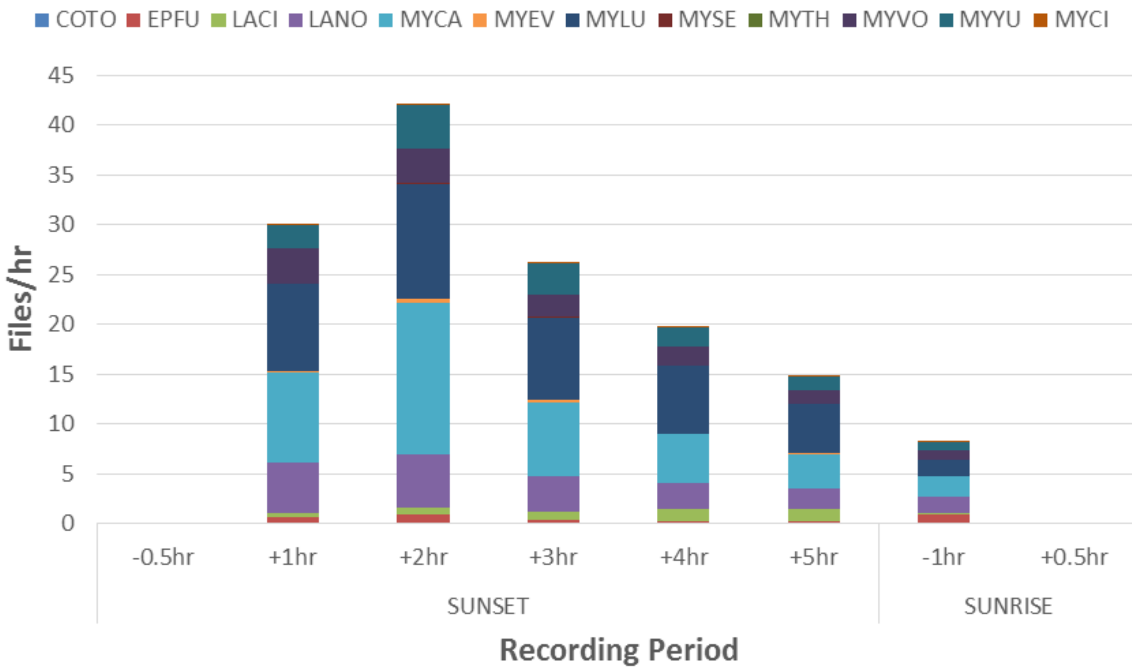

Figure 5-24: Hourly activity levels for all species of bats detected around the Lower and Mid-Arrow Lakes in 2016. Data corrected for the number of bat detectors deployed each year

Seasonal (monthly) relative abundance in 2016 indicate that bat activity (Figure 5-25) had a slight increase from May to June and reached the peak level in July. The bat activity remained high in August, which was the second most active month, before dramatically declining in September. The species proportions are relatively consistent across the five months that sampling occurred, with some exceptions. In May, MYCA and MYYU were the two most active species, accounting for over two-thirds of all detections in the month. Conversely, MYLU was proportionately less active in May than it was from June through September. The larger bat species (i.e., COTO, EPFU, LACI and LANO) appeared to be most active in July based on the number of files per hour, but they made up a higher proportion of the classified detections in September, accounting for over one-third of all detections in the month.

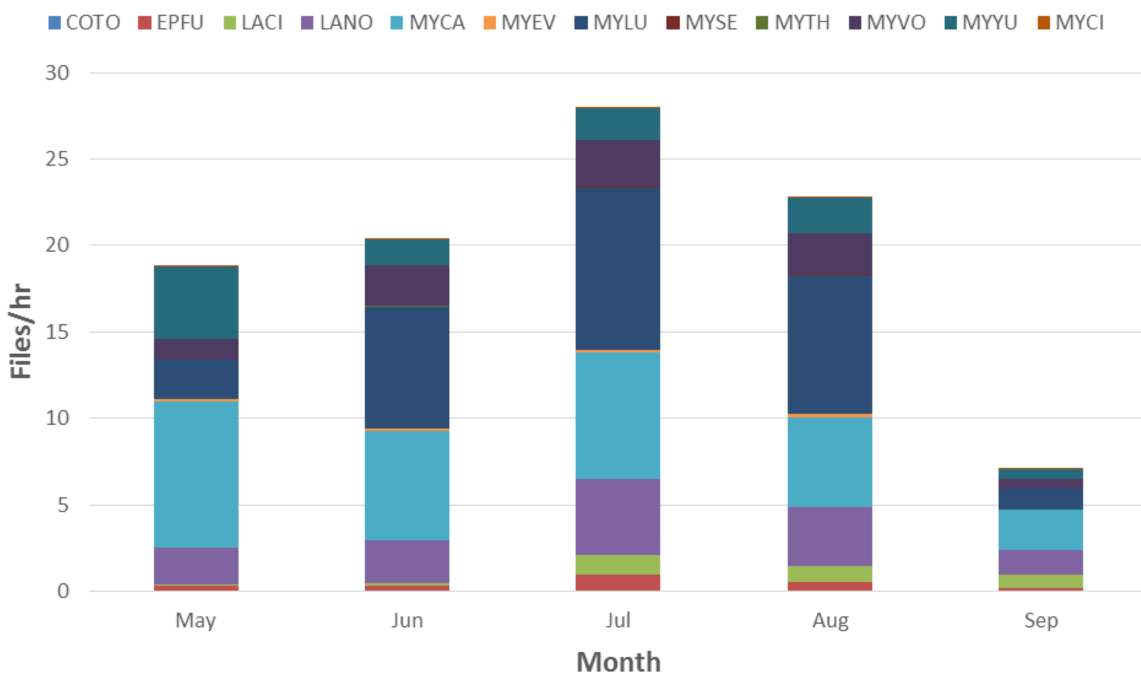

Figure 5-25: Seasonal activity levels for species of bats detected around the Lower and Mid-Arrow Lakes Reservoir, summer 2016

The number of detections from bat detectors were plotted by date to further look at activity levels of each species (Figure 5-26). Similar to the seasonal activity bar chart, some species show a pronounced peak in July, which was the busiest month for bat activity. In particular, four *Myotis* species (MYCI, MYLU, MYSE and MYVO) appear to show a spike in activity in early to mid-July, and EPFU also appears to follow this pattern to a lesser degree. The earlier peak of MYYU and later peak of LACI are also represented. The remaining species appear to fluctuate over the course of the sampling period.

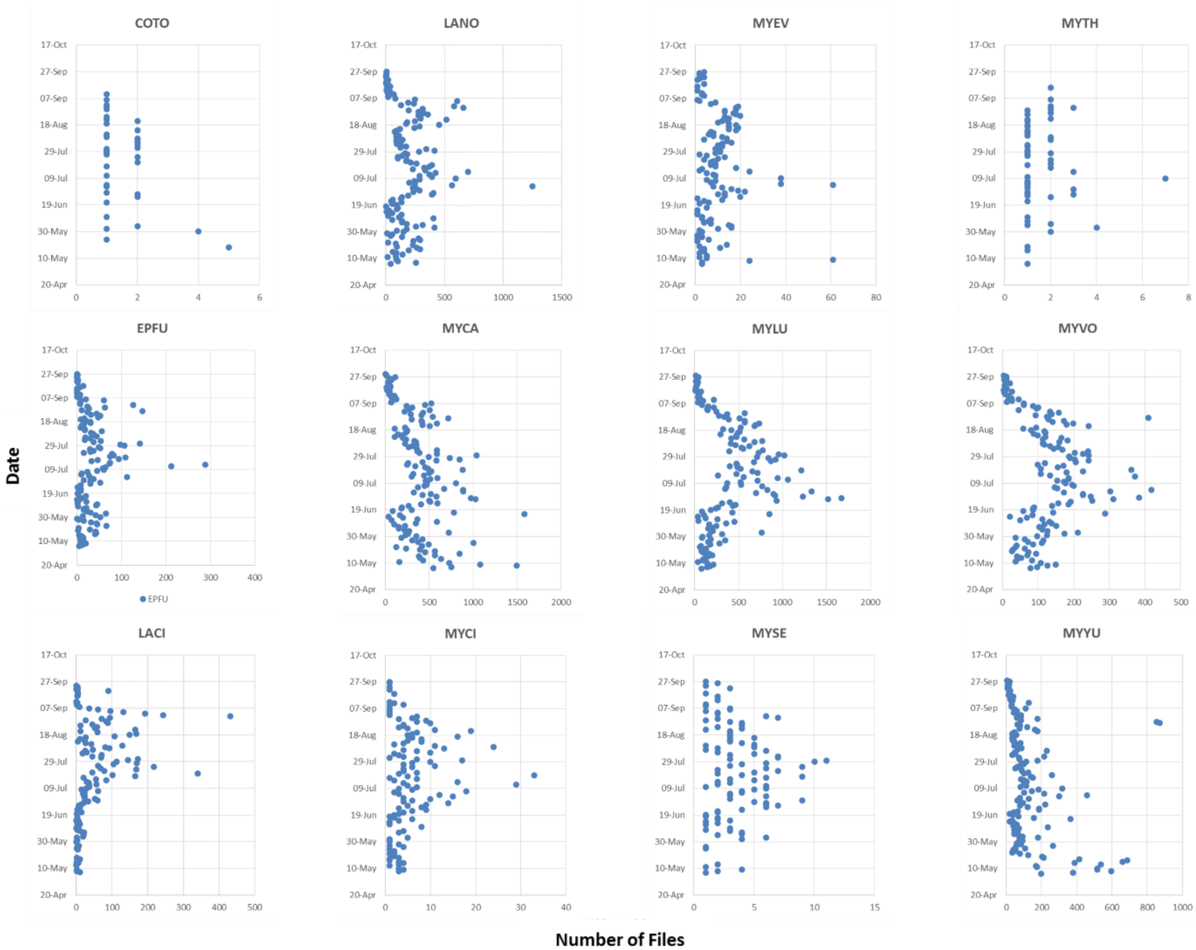

Figure 5-26: Monthly activity levels (number of files) for each species documented at the Lower and Mid-Arrow Lakes in 2016. Note varying values on x-axis. See Table 4-2 for species codes and corresponding common names.

Two sites where physical works are proposed were sampled (i.e., Burton Creek and Edgewood South) and the relative abundances of bats at these locations were compared to nearby control and treatment prescriptions (Figure 5-27). The results were not consistent between the two sites.

Burton Creek's proposed physical works location had a slightly higher bat detection rate than adjacent control and treatment areas. The two migratory tree bat species (LACI and LANO) were recorded in higher proportions at the proposed physical works site and the two most infrequently recorded species (COTO and MYTH) went undetected at the control site.

At Edgewood South, the control area had the highest activity, with a detection rate more than double that of the treatment prescription and more than threefold higher than the proposed physical works site.

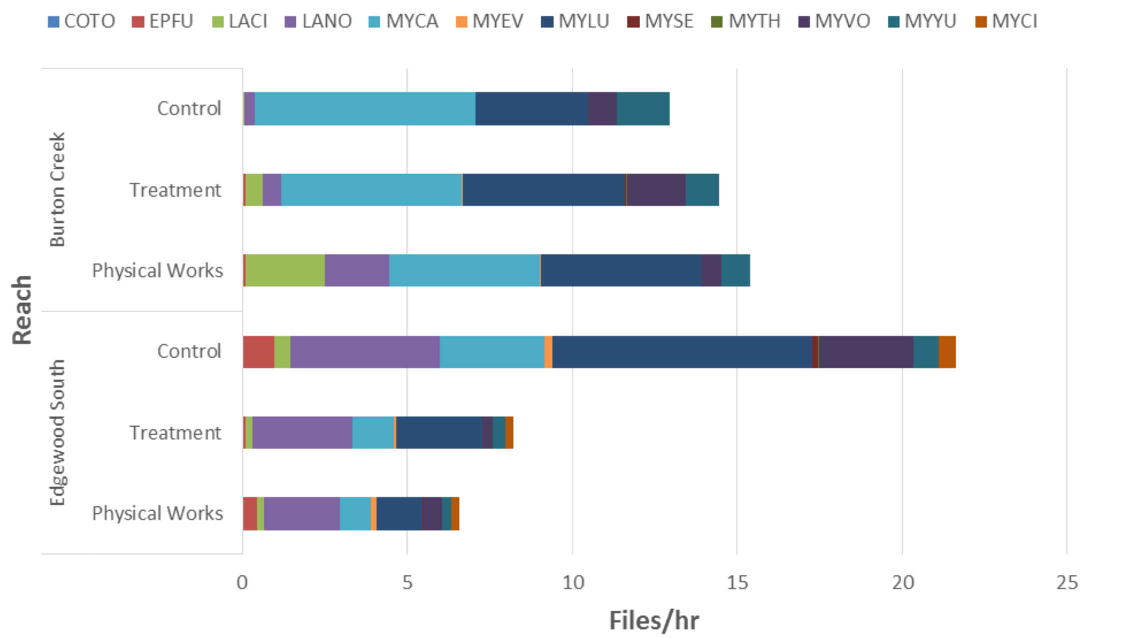

Figure 5-27: Relative abundance (files per hour) of bat species detected at control, treatment and proposed physical works sites at Burton Creek and Edgewood South, summer 2016

5.6 Terrestrial Mammals

Mammal observations (visual sightings, wildlife signs) were documented incidentally during songbird and arthropod surveys, between June 19 to 25 and from July 11 to 28 in 2016. These incidental observations do not include information about effort but contributes to our understanding of the distribution and habitat use of animals in the drawdown zone and upland locations of Arrow Lakes Reservoir.

A total of 84 observations from 5 sites and 10 species groups were recorded in 2016, consisting of 106 individual mammals (Figure 5-28). The majority of species detected were ungulate species such as deer spp. [either White-tailed Deer (*Odocoileus virginianus*) and/or Mule Deer (*Odocoileus hemionus*)] followed by Vagrant Shrew (*Sorex vagrans*). Elk (*Cervus canadensis*) sign was not detected as often as in 2015, with only 3 observations recorded during the 2016 monitoring year. The most frequent sign recorded were: tracks, dead animals (from pitfall trap captures) and pellet groups (Figure 5-28). Only Vagrant Shrews (*Sorex vagrans*) and one individual *Sorex* sp. (worn teeth obscured species determination) were detected in 2016 from pitfall trap captures. In previous years, Cinereus Shrew (*S. cinereus*) has also been reported from Arrow Lakes Reservoir.

Grizzly bear (*Ursus arctos*) is provincially blue-listed and listed as Special Concern by COSEWIC. Although this species was not documented from the drawdown zone in 2016, evidence (scat) was noted near the Mosquito Creek wetland upland reference area. In the past we have documented Grizzly Bear presence in the drawdown zone of Edgewood South and the drawdown zone and upland area of Mosquito Creek.

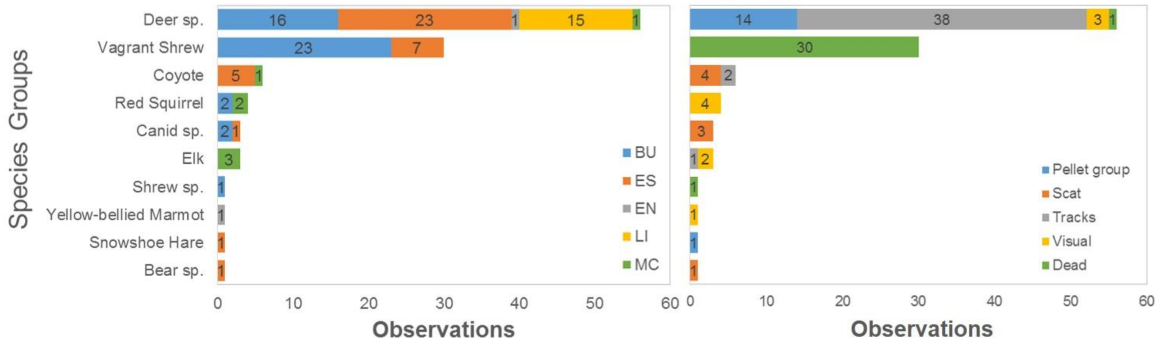

Figure 5-28: Total incidental mammal observations by site (left) and by observation type (right) recorded in the Arrow Lakes Reservoir, 2016. Deer species were pooled due to difficulty in differentiating these species by pellets/tracks. Sites: ES = Edgewood South; EN = Edgewood North; LI= Lower Inonoaklin; BU = Burton Creek; MC = Mosquito Creek

5.7 Amphibians and Reptiles

Amphibian and reptile data is presented as incidental data for CLBMON-11B1. A full report on amphibians and reptiles in the Arrow Lakes Reservoir is presented under CLBMON-37 (Hawkes and Tuttle 2013; Hawkes et al. 2015).

Over the duration of the project we have recorded five amphibian species from the drawdown zone of Arrow Lakes Reservoir: Western Toad (*Anaxyrus boreas*), Columbia Spotted Frog (*Rana luteiventris*), Pacific Chorus Frog (*Pseudacris regilla*), and Long-toed Salamander (*Ambystoma macrodactylum*). The only amphibian at risk documented in the drawdown zone is the Western Toad, which is federally a species of Special Concern and blue-listed provincially. Three individual amphibians were incidentally collected during arthropod pitfall sampling: two juvenile Long-toed Salamander and one juvenile Western Toad.

In 2016 we documented all the above amphibians with the exception of Columbia Spotted Frog. Additionally, we reported five reptile species to use the drawdown zone or immediately adjacent upland habitat, including: Western Terrestrial Gartersnake (*Thamnophis elegans*), Common Gartersnake (*Thamnophis sirtalis*), Rubber Boa (*Charina bottae*), Northern Alligator Lizard (*Elgaria coerulea principis*) and Western Skink (*Plestiodon skiltonianus*). Western Skink and Rubber Boa are both federally listed as Special Concern, while the skink is also blue-listed provincially. In 2016 we documented all the above reptiles except the Rubber Boa.

6.0 DISCUSSION

CLBMON-11B1, initiated in 2009, is a long-term wildlife monitoring project that aims to assess the efficacy of revegetation prescriptions in enhancing the suitability of habitats in the drawdown zone for wildlife, and to develop a minimum of three wildlife enhancement prescriptions that can be implemented in the drawdown zone to further improve habitat suitability. Based on previous recommendations the current study focuses on arthropod, songbird, and bat communities, all selected for their potentially measurable responses to treatment effects in the drawdown zone of Arrow Lakes Reservoir.

The revegetation prescriptions and physical works projects in the drawdown zone may affect prey populations (e.g., terrestrial arthropods) with potential to alter the suitability of foraging habitat for predators of those arthropods (songbirds and bats). The direction and magnitude of changes in arthropod populations is being tracked over time and will serve as a metric to assess the efficacy of each revegetation prescription applied in the drawdown zone.

Consistent with previous years [e.g., Hawkes et al. 2014; Sharkey et al. 2016 (draft)], terrestrial arthropod and songbird assemblages partitioned between the drawdown zone and adjacent upland habitats. Thus, assemblages were similar among the revegetation treatment and control areas of the drawdown zone. This result is expected, given the impact reservoir operations have on wildlife habitat in the drawdown zone of the Arrow Lakes Reservoir, and the limited success of revegetation treatments.

Within the drawdown zone, results of the monitoring to date indicate that any relationships between the relative abundance of arthropods, or songbirds, in response to revegetation prescriptions applied in the drawdown zone must be biologically small effects, which are likely obscured by multiple potential sources of variation, and are also difficult to detect due to small sample size. Interestingly, arthropod biomass tended to have lower biomass values in pitfall traps at revegetation areas in both 2015 and 2016. While this trend was not evident in Malaise trap samples, the ground-dwelling community collected by pitfall traps may be more representative of local arthropod densities. Future years of monitoring should elucidate whether this pattern holds.

No distinct groupings in terrestrial arthropods and songbirds were seen between control and treatment areas within the drawdown zone, suggesting no obvious effect of the revegetation treatments. Future analyses will explore whether other sources of variation might have obscured a treatment effect, including site specific differences in topography, proximity to adjacent habitat, fluctuating reservoir levels, annual natural variation, and inconsistent revegetation success across sites. Across years, these results have been consistent. Where site-specific differences between treatment and control plots were observed, we were unable to draw any causal relationships with the revegetation sampling because pre-treatment (baseline) sampling was not conducted to assess pre-existing differences between treatment and control polygons.

Songbirds and arthropods are suitable indicators to assess changes in habitat quality induced by the revegetation prescriptions. For example, many arthropod species are sensitive to changes in vegetation cover and soil surface moisture/temperature. Particularly for beetle species (of Carabidae and Staphylinidae) that develop in the upper layers of soil during their larval stages, they are highly selective to particular microhabitats. Spider species are strongly tied to changes in vegetation structure, as this provides different niches for spiders that specialize in different modes of prey capture. Sites with bare ground are usually dominated by spiders that do not require webs for prey capture (e.g., Wolf spiders, Crab spiders). Sites with low herbs such as Carex/grasses may provide a niche for the funnel-web building spiders. Higher vegetation provided by willows/shrubs provides habitat for web-building spiders of varioius species. Forested habitats provide numerous additional niches not provided by open habitats. Likewise, songbirds potentially respond to changes vegetation structure, for example through their nesting requirements. Areas containing cottonwood stakes and sedges are likely to additional provide habitat for bird speices that is not available in drawdown zone areas with bare ground. Future years of monitoring will examine species specific responses in further detail.

Acoustic monitoring of bats in the drawdown zone has resulted in the detection of 12 bat species in mid- and lower Arrow Lakes Reservoir. These species classifications were determined using machine learning algorithms, and have the potential to make classification errors, thus we used conservative settings when determining species identifications. Nevertheless, the results indicate that a diverse species assemblage of bats are utilizing drawdown zone habitats. The data were not correlated with a specific treatment but provided an overview of the distribution and occurrence of bats using the drawdown zone of the reservoir. The ability to correlate the bat activity to arthropod biomass will be examined in future reports, particularly for examining before and after impacts of wildlife physical works projects. The current results in bat activity and species composition by site is likely reflective of the local foraging potential and will be used as baseline data for future physical works implementation.

The effectiveness monitoring program developed and implemented in mid- and lower-Arrow Lakes Reservoir is scheduled to continue in 2017, but some changes are recommended. These methods should also be appropriate for monitoring the efficacy of proposed wildlife physical works discussed in Hawkes and Howard (2012) and Hawkes and Tuttle (2016).

6.1 Management Questions and Hypotheses

6.1.1 Are the revegetation and the wildlife physical works projects effective at enhancing wildlife habitat in the drawdown zone?

Revegetation

Based on the results obtained in 2016, there is little evidence to suggest that revegetation prescriptions are enhancing wildlife habitat in the drawdown zone for the taxa being monitored. From a revegetation perspective, the application of treatments in the drawdown zone does not appear to influence the use of the drawdown zone by songbirds or terrestrial arthropods. There are several reasons why this might be: 1) the size of the revegetation treatments and their proximity to adjacent habitat may limit use by wildlife; 2) the type of revegetation prescription (e.g., live stake vs. plug seedling) may not be preferred habitat; 3) the lack of replication at the treatment level makes it difficult to detect a signal, even if one exists; 4) variability in administration and success/survival of revegetation treatments; 5) pre-treatment within-site, and among-site variation.

Physical Works

Development of potential wildlife physical works are ongoing. Projects have been identified (Hawkes and Tuttle 2016) and the first stage of implementation planned for 2017. This question cannot be answered until the wildlife physical works are completed and monitored. Considerable data have been collected on wildlife usage under existing conditions, and this program is adaptable, as physical works planning becomes better defined. Having wildlife usage well documented prior to implementation of physical works provides a powerful assessment of before-after effects on a case by case basis.

6.1.2 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?

Revegetation

To date, the evidence to suggests that revegetation prescriptions are not highly effective at enhancing wildlife habitat in the drawdown zone. The clearest evidence of increased productivity is the observation of a few birds nesting in revegetation treatments. Future years of monitoring songbird nesting success may provide more data with respect to productivity of songbird species in the drawdown zone. The biomass of arthropods is another key response measure currently used as a measure of habitat productivity. To date there has been no clear trend to support increased arthropod biomass in the drawdown zone due to the revegetation prescriptions.

Physical Works

Development of potential wildlife physical works are ongoing. Projects have been identified (Hawkes and Tuttle 2016). This question cannot be answered until the wildlife physical works are completed and monitored. It is expected, however, that physical works which create wetland habitat in the drawdown zone will have a high potential to increase productivity.

6.1.3 Are some methods or techniques more effective than others at enhancing wildlife habitat in the drawdown zone?

Revegetation

At present, it is unknown if live-staking or plug seedling prescriptions will be more effective at enhancing wildlife habitat in the drawdown zone. The ability to answer this question has been hampered by the relatively small number of areas treated in the drawdown zone, the inconsistency/variability in treatment applications, the size of the areas treated, the lack of replication associated with each of the component revegetation prescriptions, annual variability in conditions (reservoir-related and otherwise), considerable natural variability within and among sites, and the lack of success and low survivorship of revegetation treatments. These factors have limited the use of inferential statistics to determine whether some methods are more effective than others. Initial site selection could not take into account plant survival, and initial monitoring has instead documented habitat suitability at relatively few sites, in detail, over time. Following the 2017 field season, there may be opportunities to reassess where the component revegetation treatments have been successful (e.g., using CLMBON-12 results), and to examine revegetation treatments at successful sites in more detail.

Physical Works

Development of potential wildlife physical works are ongoing. Projects have been identified (Hawkes and Tuttle 2016) and the first stage of implementation planned for 2017. This question cannot be answered until the wildlife physical works are completed and monitored.

6.2 Management Questions - Summary

The methods currently used are appropriate for collecting data that can be used to answer specific questions. For others, additional approaches may be required. For example, to answer questions regarding songbird productivity, increasing nest search effort is suggested. In other cases, increasing the total area or number of areas revegetated would alleviate problems of small sample size and small treatment areas. Continued monitoring of arthropod, songbird, and bat populations in the drawdown zone and upland reference sites has the potential to detect changes in habitat use over time. Sampling in each year is recommended to reduce uncertainty associated with inter-annual variation of all taxa sampled.

Additionally, we recommend pre-treatment sampling at proposed physical works areas in order to develop a baseline for assessing treatment differences in future monitoring years. Until the physical works are implemented in Arrow Lakes Reservoir, we will not be able to answer questions regarding their effectiveness. Our ability to address each of the management questions is summarized below.

Table 6-1: Relationships between management questions (MQs), methods and results, sources of Uncertainty, and the future of project CLBMON-11B1

MQ	Able to Address MQ?	Scope		Sources of Uncertainty/Limitations
		Current supporting results	Suggested modifications to methods where applicable	
1. Are the revegetation and the wildlife physical works projects effective at enhancing wildlife habitat in the drawdown zone?	Partially	Data collected in control, treatment, and upland reference sites indicate that wildlife are using all treatment areas. Current results show little difference between control and treatment plots.	• Continue to focus assessments of revegetation effectiveness where prescriptions are most successfully established i.e., Lower Inonoaklin, Edgewood South etc. • Conduct pre-treatment sampling prior to physical works implementation for all taxa (where possible, e.g., Burton Creek).	• Due to lack of pre-treatment sampling, it is unknown if revegetation has enhanced wildlife habitat in the drawdown zone. • Natural annual population variation and seasonality • Lack of replication • Mixed success of revegetation program • Previous bi-annual sampling • Variable reservoir operations • Physical works have not been implemented
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?	Partially	To date, revegetation prescriptions do not appear to effectively improve wildlife habitat. In general, no multi-year trend has been observed for arthropod biomass or songbird communities between the control and treatment areas within sites.	• Continue annual sampling • Nest searching for songbirds was initiated in 2016. Increase nest search effort to better measure bird productivity • Continue monitoring with autonomous recording units, targeting areas of proposed wildlife physical works • Conduct pre-treatment sampling prior to physical works implementation for all taxa (where possible, e.g., Burton Creek).	• Lack of appropriate baseline (sampling did not occur prior to the application of the revegetation prescriptions) • Natural annual population variation and seasonality • Lack of replication • Mixed success of revegetation program • Previous bi-annual sampling • Variable reservoir operations • Physical works have not been implemented
3. Are some methods or techniques more effective than others at enhancing wildlife habitat in the drawdown zone?	Partially	Revegetation treatments were most successfully established at Lower Inonoaklin and Edgewood South. Whether this is due to the treatment types applied or site-specific variation is not known.	• Consider adding replicates of certain revegetation prescriptions. • Increase the size (total area treated) of some existing revegetation areas.	• Lack of appropriate baseline (sampling did not occur prior to the application of the revegetation prescriptions) • Natural annual population variation and seasonality • Lack of replication • Mixed success of revegetation program • Variable reservoir operations

7.0 RECOMMENDATIONS

1. **Annual monitoring of CLBMON-11B1.** This approach would ensure that appropriate before- and after-impact data are collected at the proposed physical works locations (i.e., Lower Inonoaklin Road, Edgewood South, and Burton Creek). Collecting songbird and arthropod data on an annual basis would also provide a better indication of the annual variability associated with those species groups and their use of the drawdown zone (with particular emphasis on the use of control and treatment sites). Deploy autonomous recording units to monitor bats at additional sites, especially in areas proposed for physical works. Once the proposed physical works are implemented, annual sampling at those locations would serve to assess the effectiveness of those physical works using a traditional before-after-control-impact (BACI) study design (Smith 2002).
2. **Increase nest search effort to study bird productivity** in the drawdown zone. Conduct targeted surveys within revegetated areas and adjacent controls.
3. **Monitor spring and fall migrant waterfowl and shorebirds** in proposed physical works areas to obtain a baseline dataset associated with these group to be able to assess if constructed wetlands or other physical works will provide habitat for shorebirds during these periods.
4. **Consider increasing the total area revegetated** in the drawdown zone (i.e., expand existing treatment areas) or add additional treatment areas of the same prescriptions applied previously to increase the sample size.
5. **Combine data from CLBMON-12 with CLBMON-11B1** to enable an assessment **of revegetation effectiveness** (i.e., survival, abundance, health) of the revegetation treatments to the enhancement of wildlife habitat in the drawdown zone of Arrow Lakes Reservoir.
6. **Consider modifications to the study design** to better assess treatment effects, to reduce uncertainties related to study design, issues of small datasets, and a lack of pre-treatment data. This could include specific studies of certain treatments relative to specific taxa (e.g., sedges and arthropods). Implementing recommendation 5 could assist in this regard.

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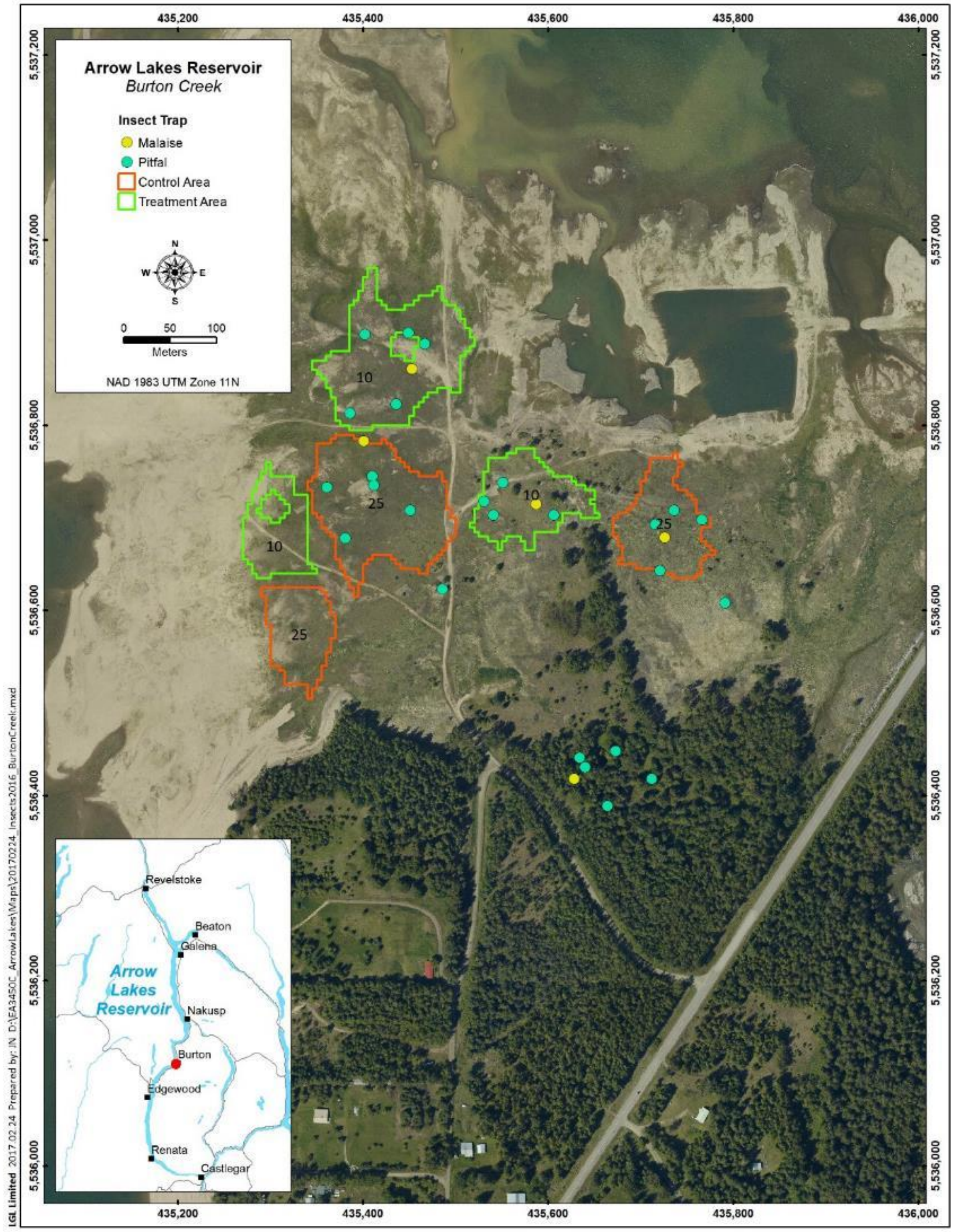
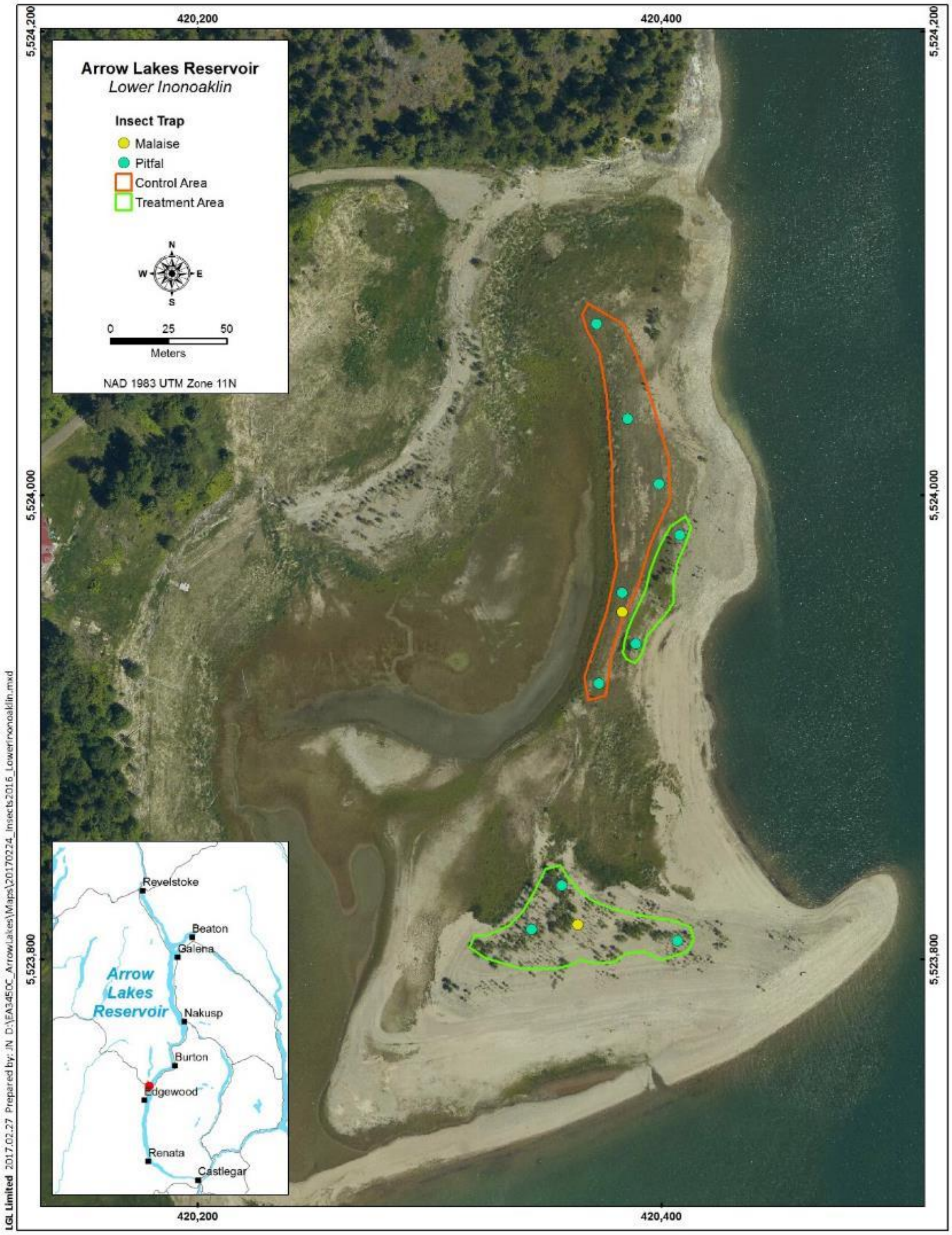
9.0 APPENDICES

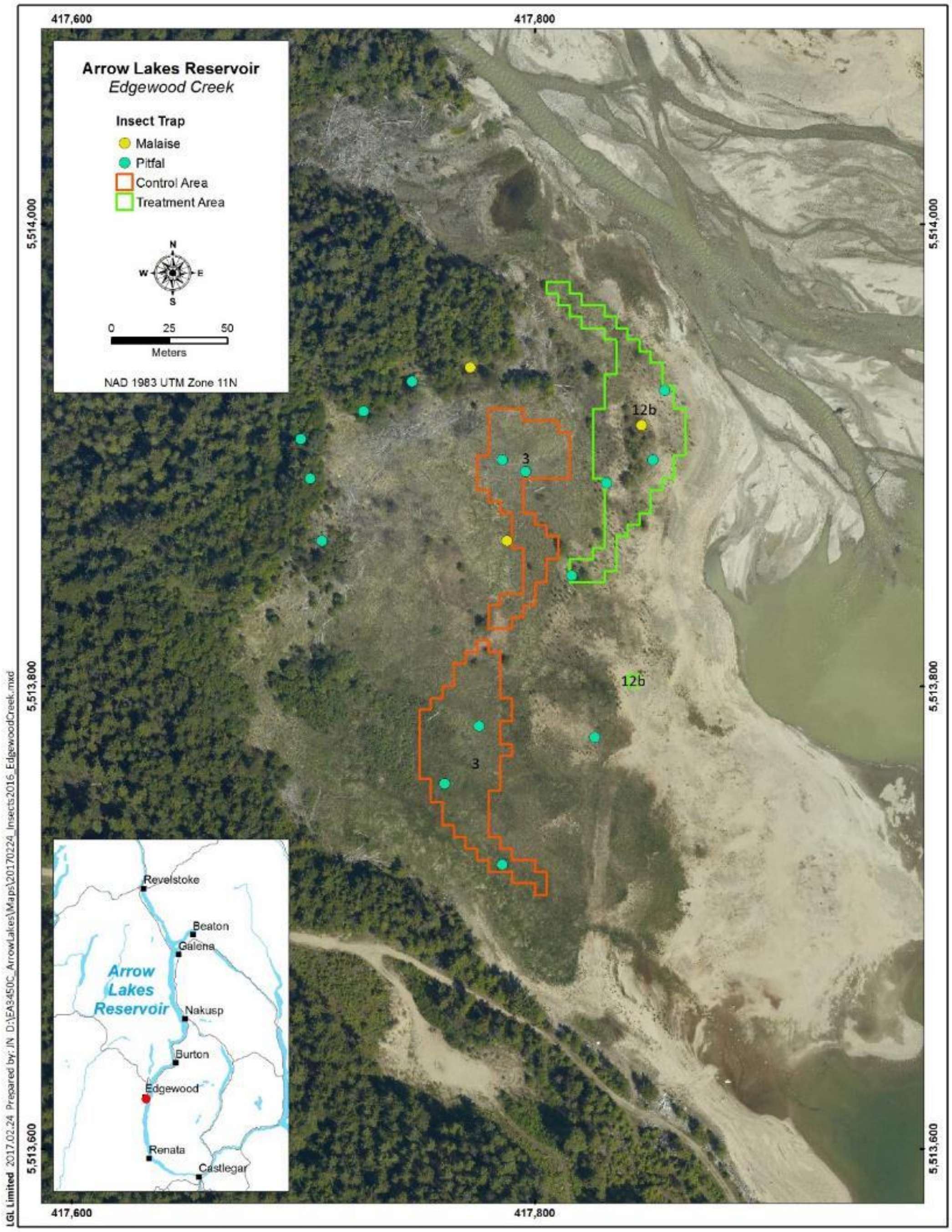
Appendix A: Maps of Malaise and pitfall trap locations for 2016



Map 1: Distribution of Malaise and pitfall traps at Burton Creek, 2016

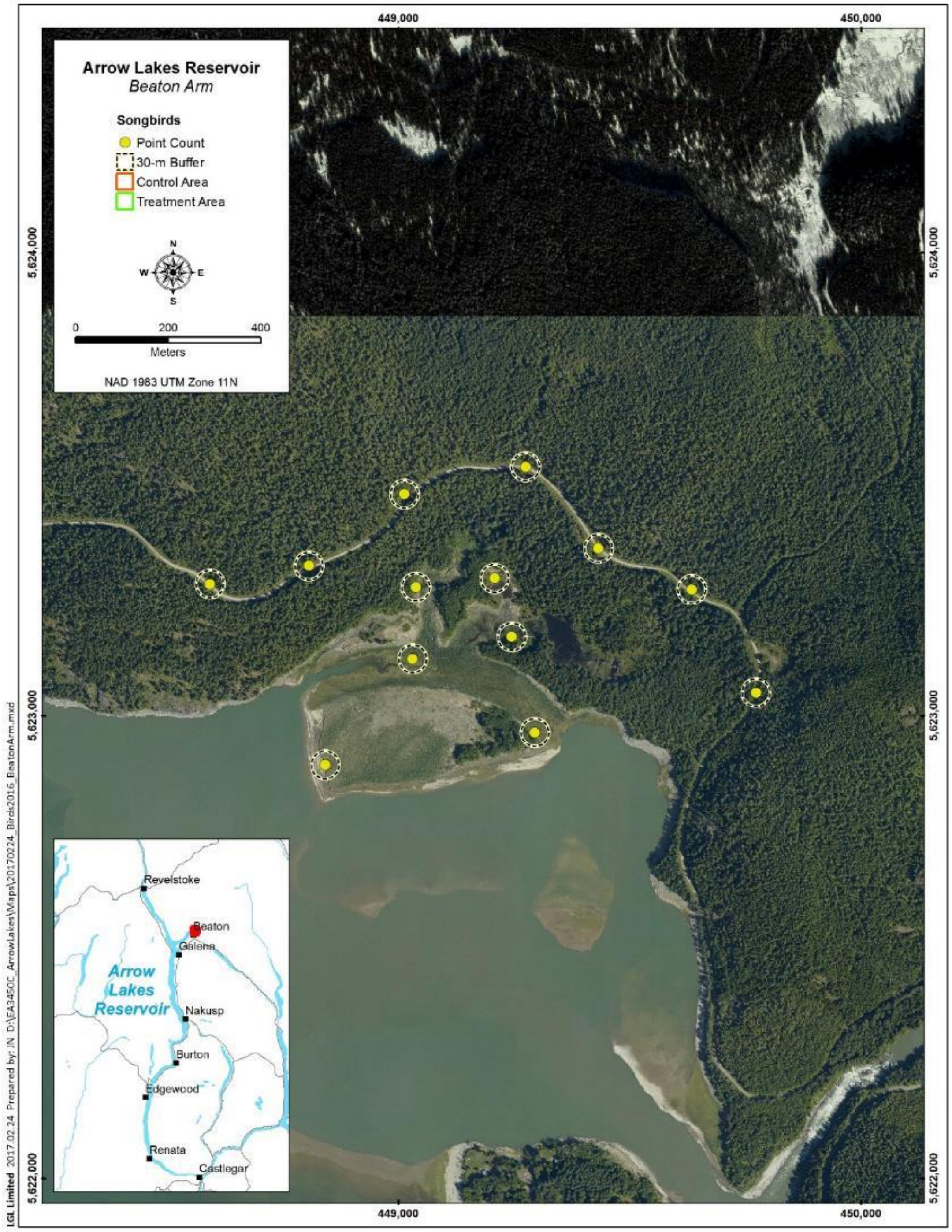


Map 2: Distribution of Malaise and pitfall traps at Lower Inonoaklin, 2016

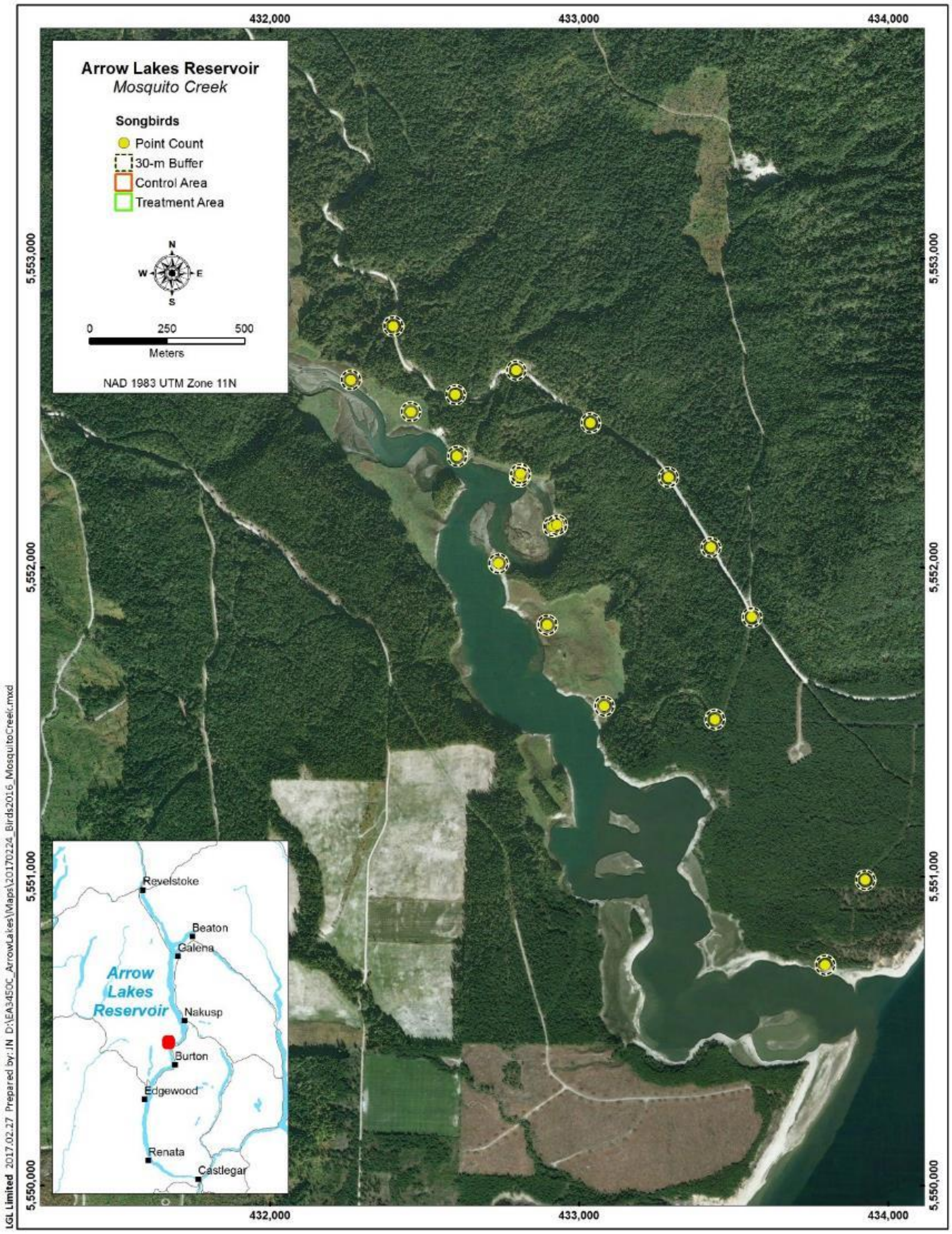


Map 3: **Distribution of Malaise and pitfall traps at Edgewood South, 2016**

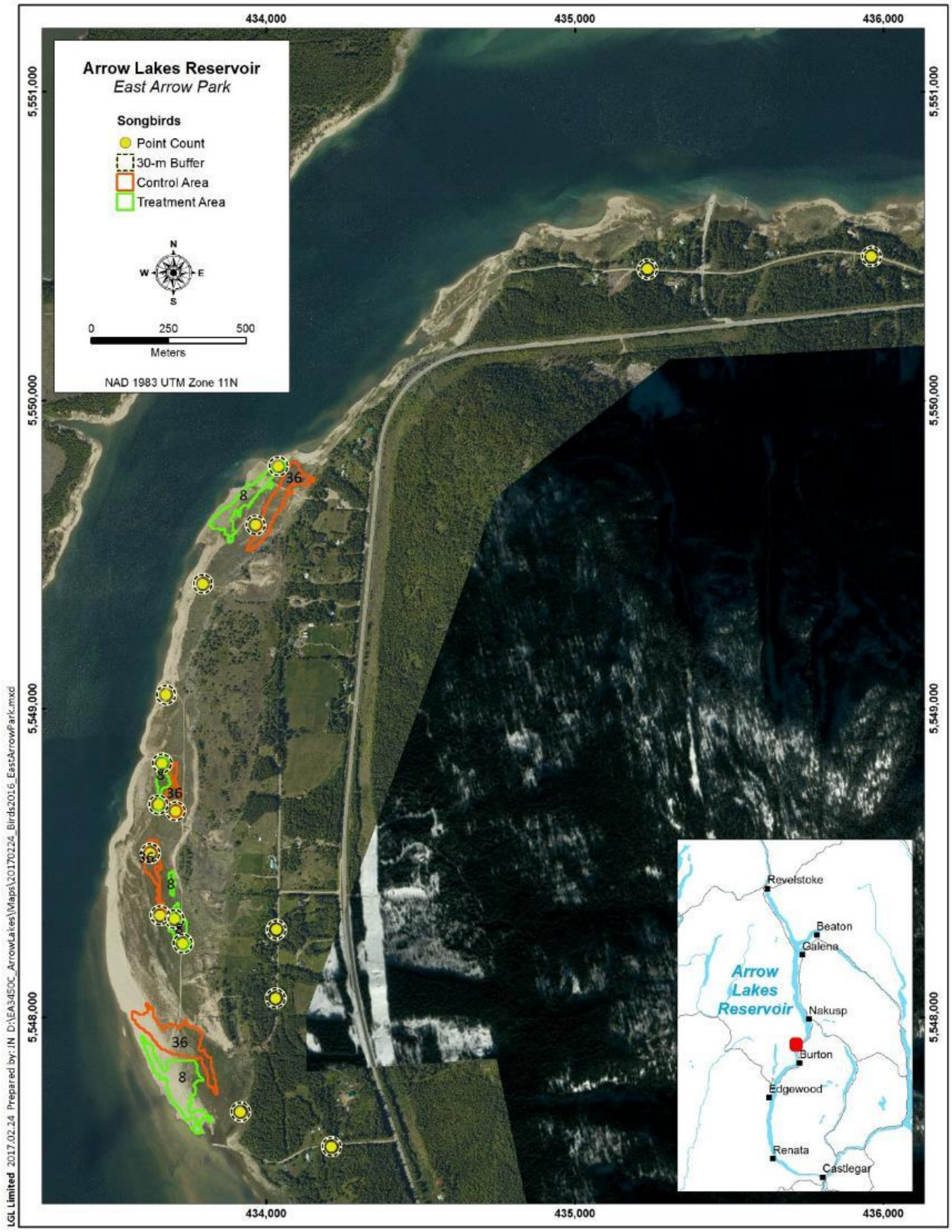
Appendix B: Maps of songbird point count stations for 2016



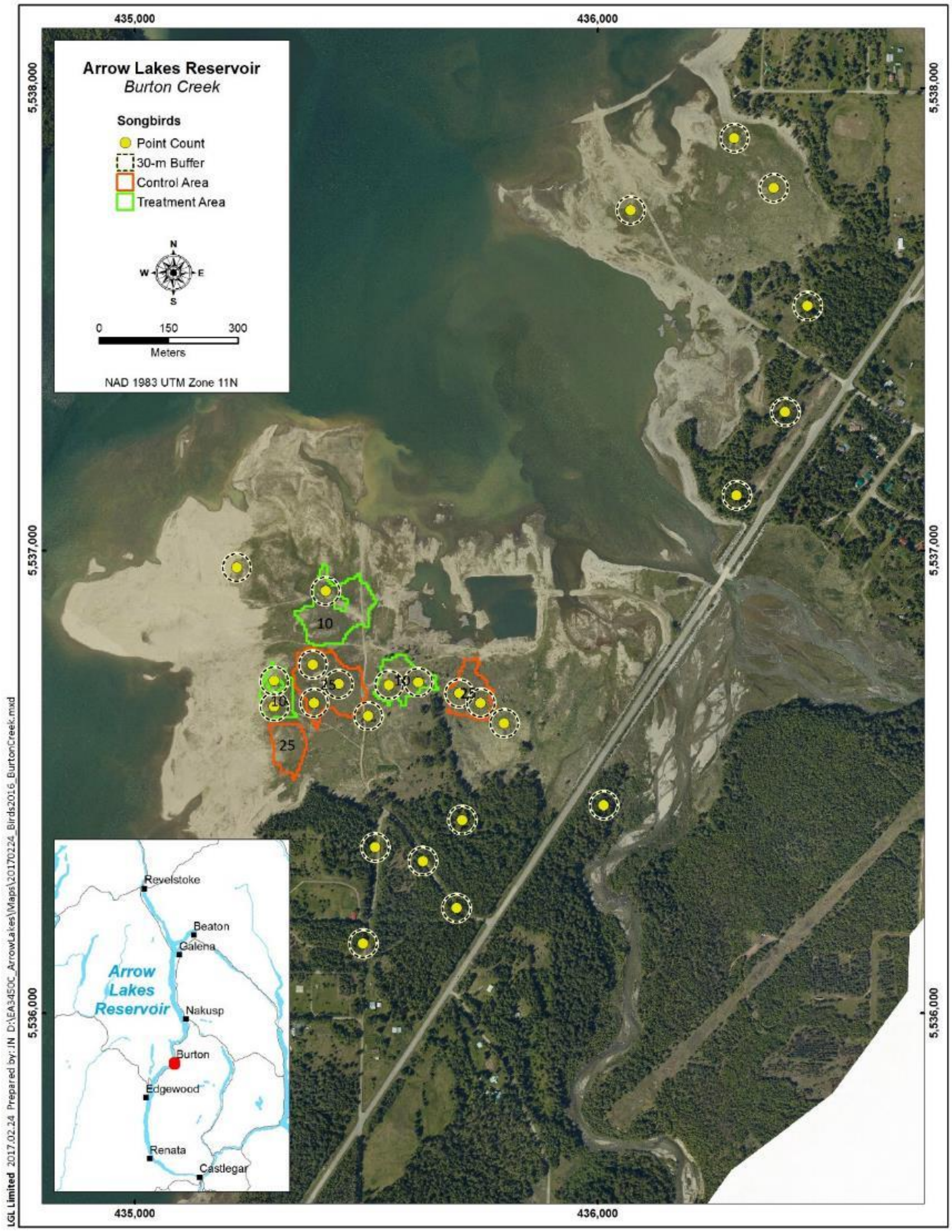
Map 4: Distribution of songbird point count stations at Beaton Arm, 2016



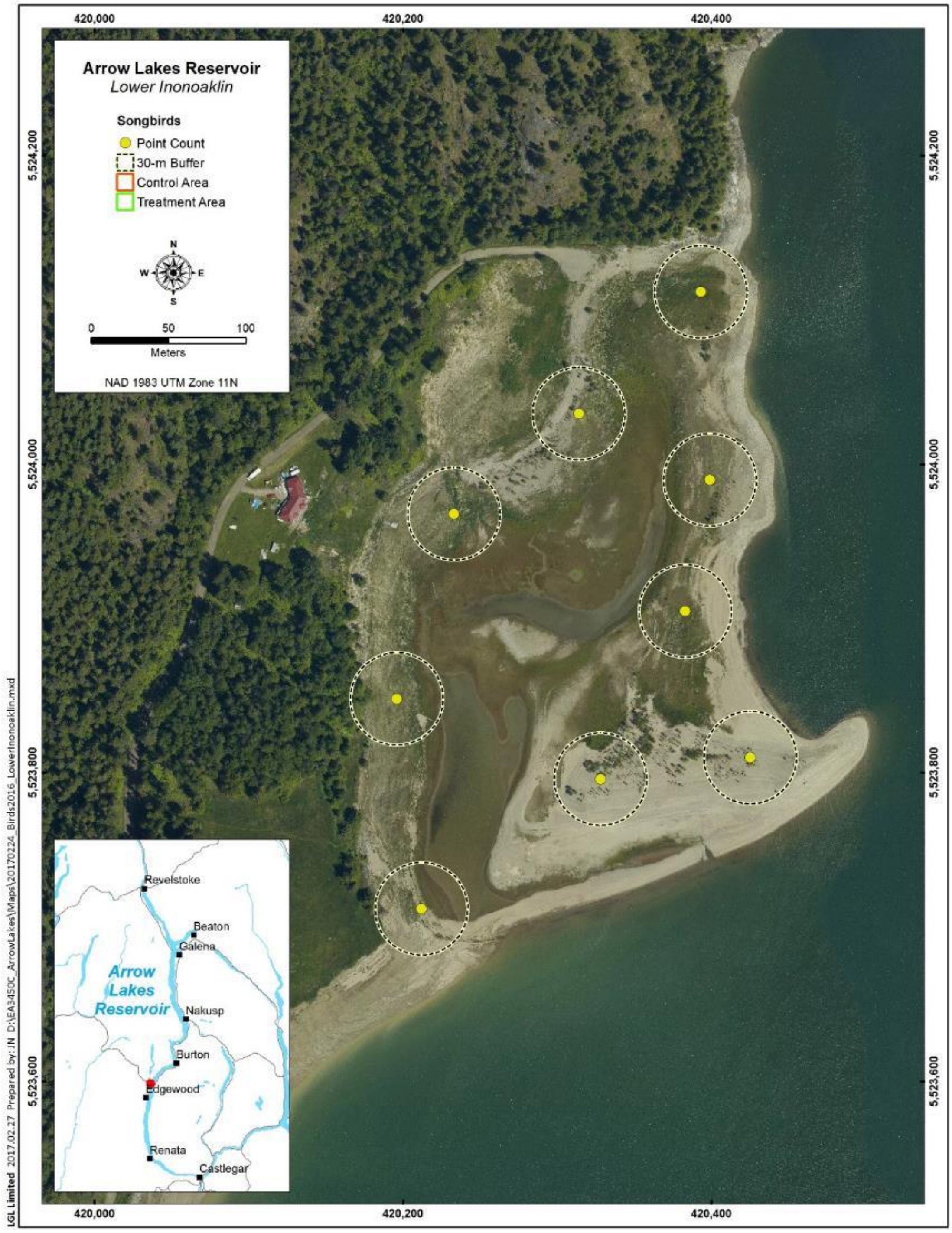
Map 5: **Distribution of songbird point count stations at Mosquito Creek, 2016**



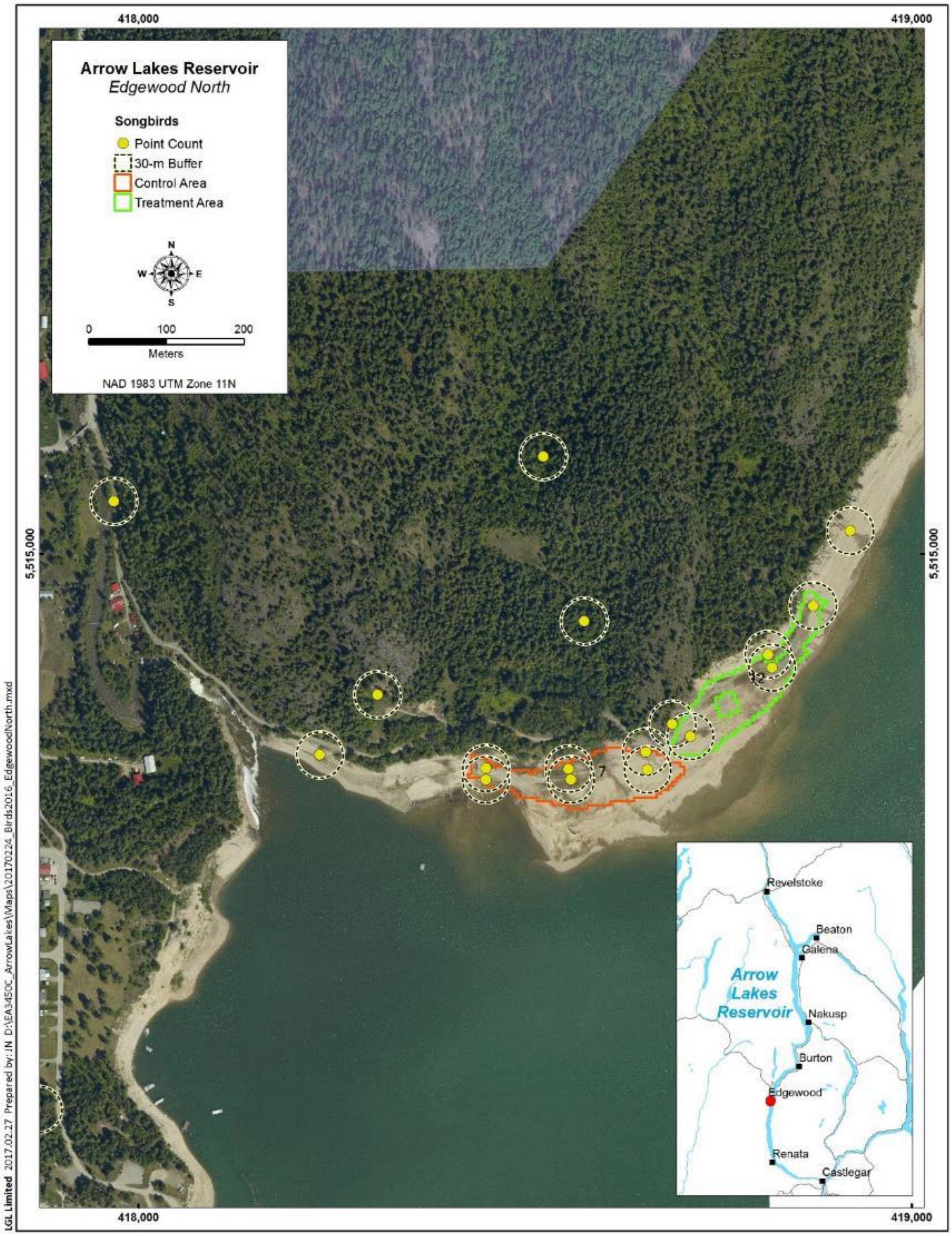
Map 6: Distribution of songbird point count stations at East Arrow Park, 2016



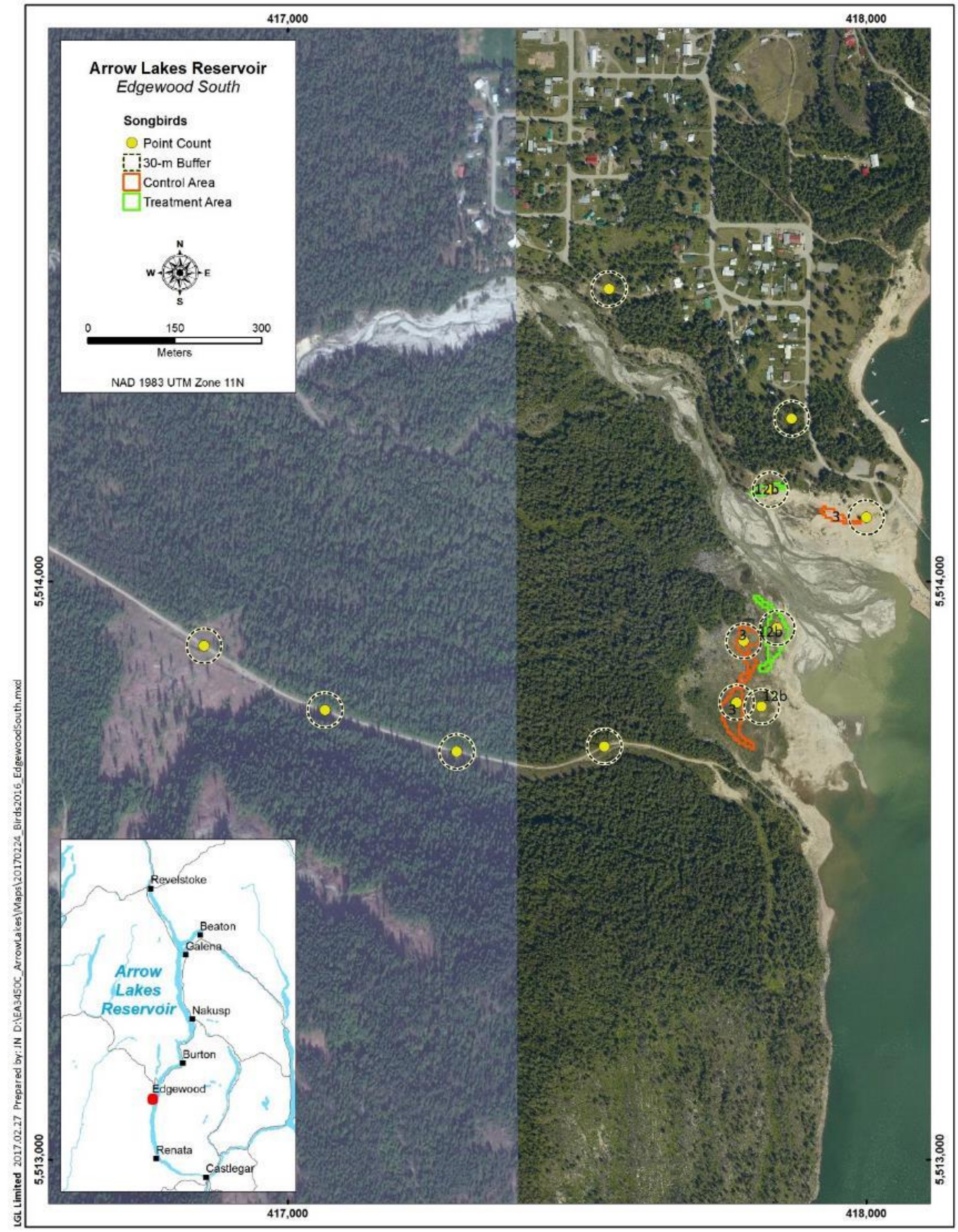
Map 7: **Distribution of songbird point count stations at Burton Creek, 2016**



Map 8: Distribution of songbird point count stations at Lower Inonoaklin, 2016

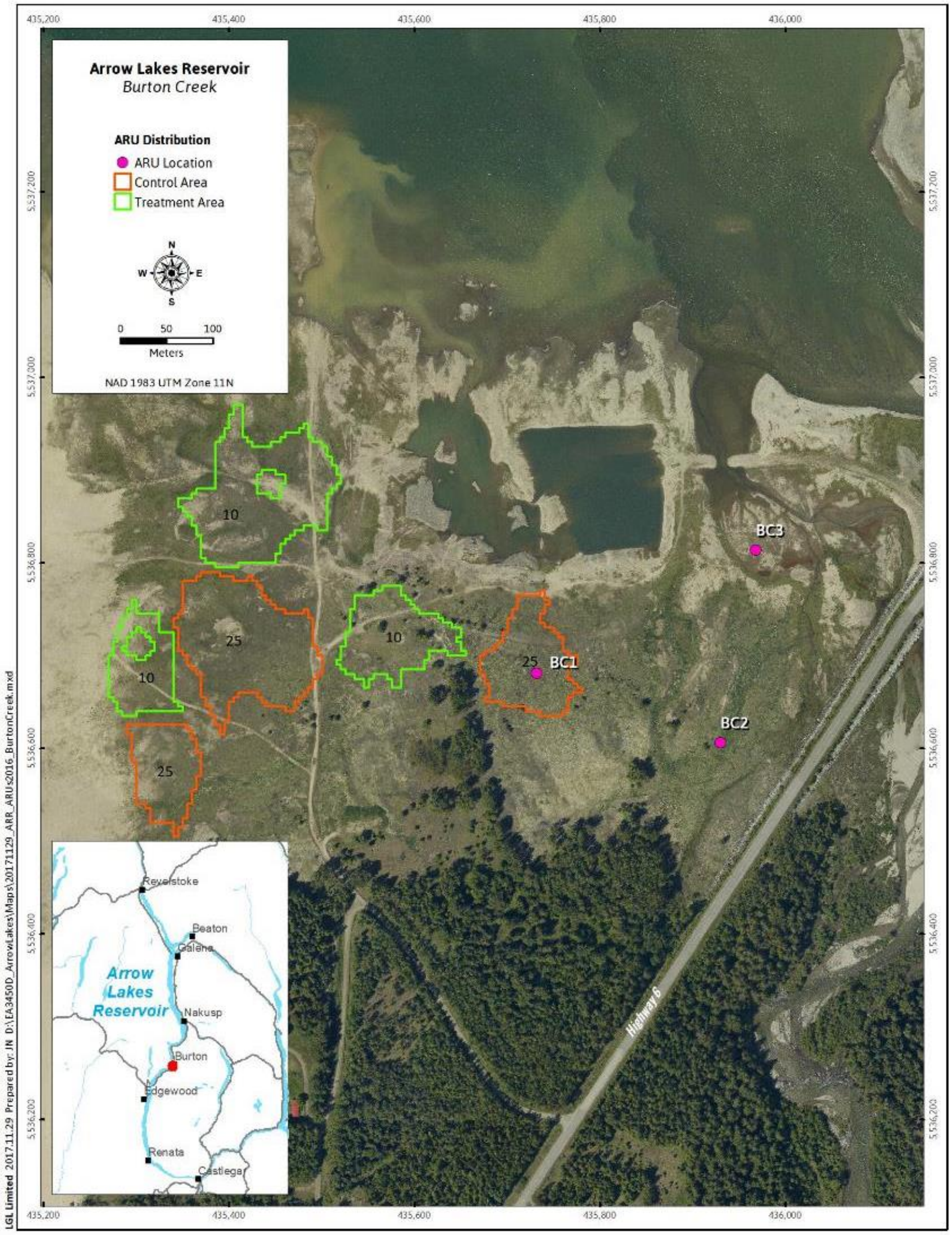


Map 9: **Distribution of songbird point count stations at Edgewood North, 2016**

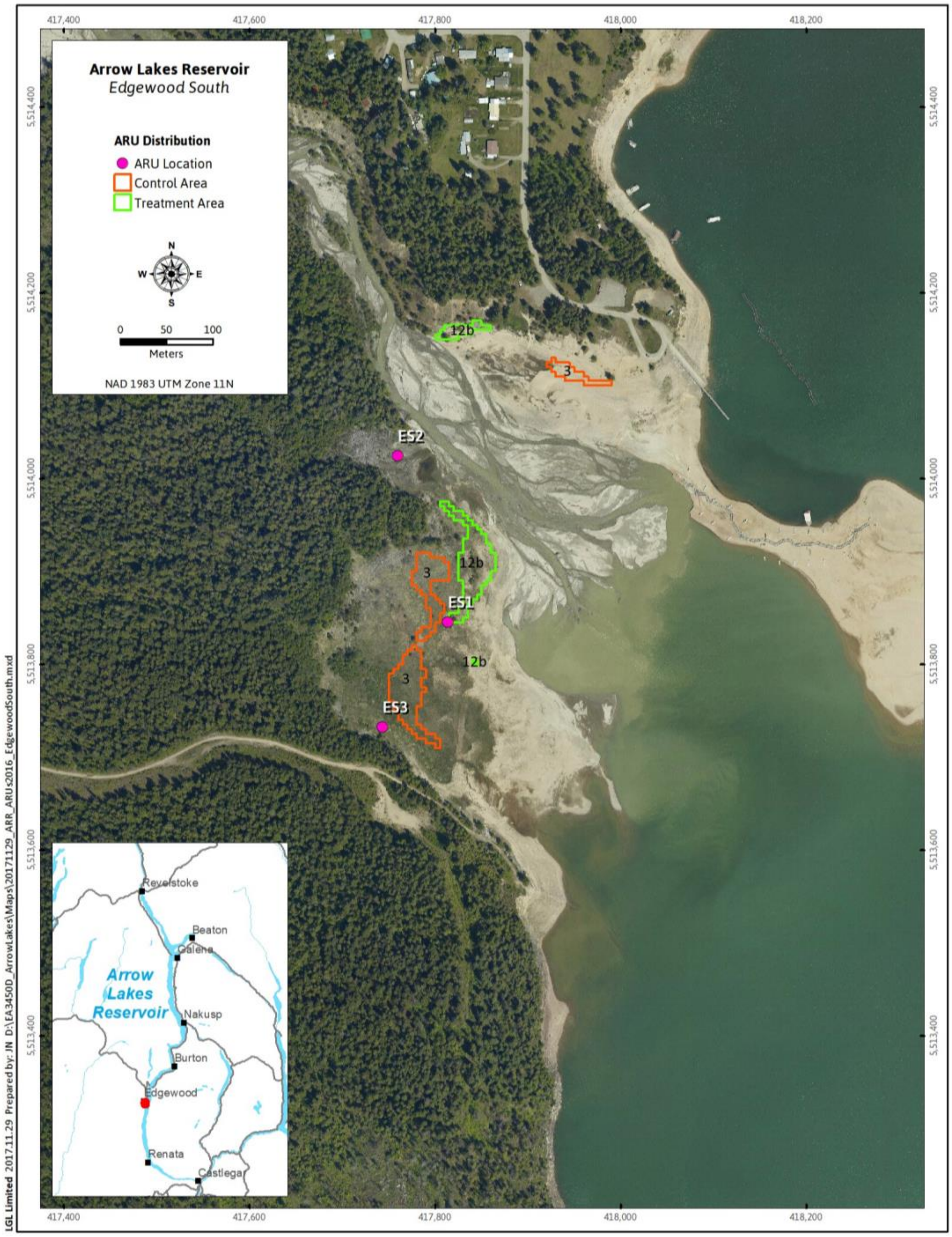


Map 10: Distribution of songbird point count stations at Edgewood South, 2016

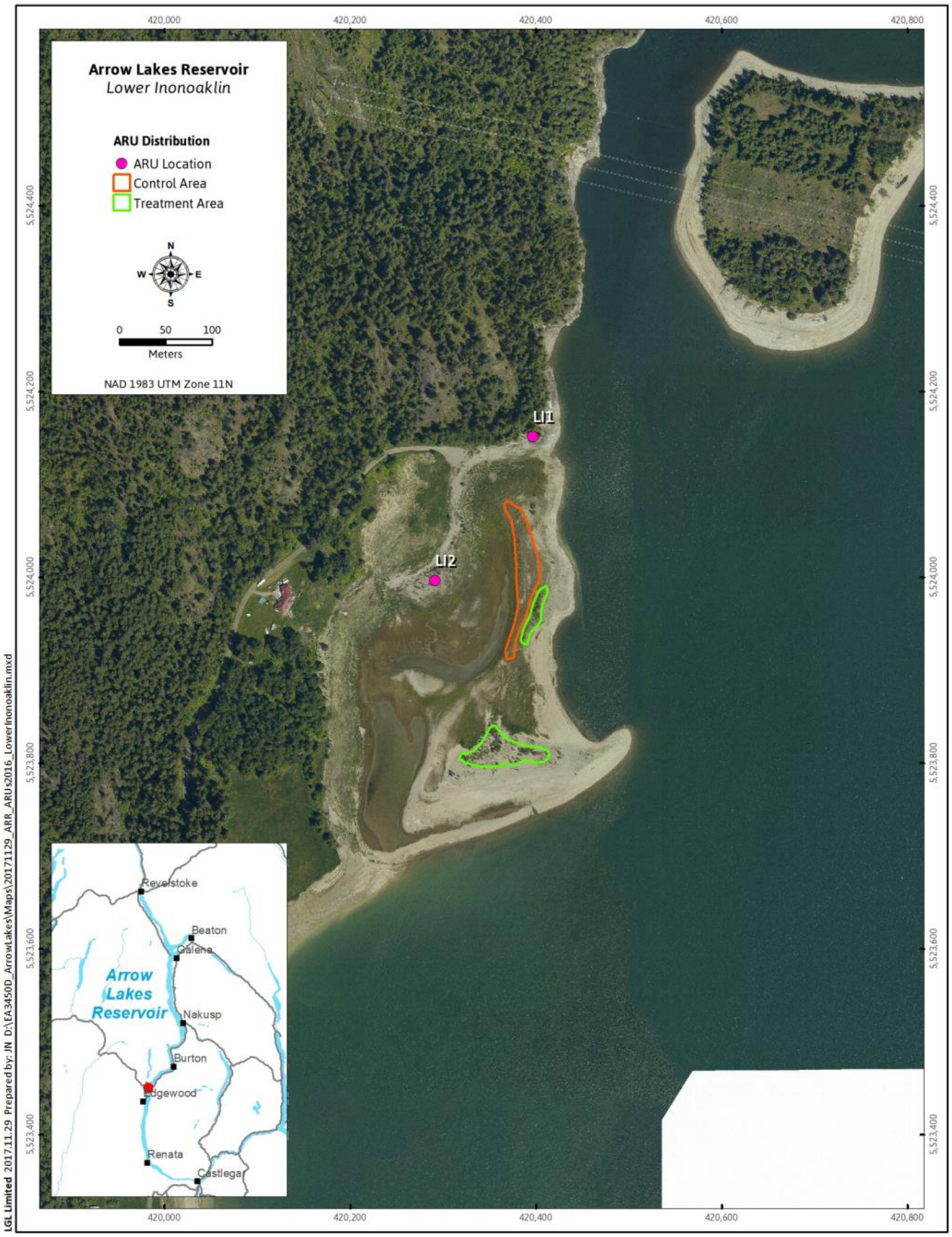
Appendix C: Maps of bat detector (ARU) locations for 2016



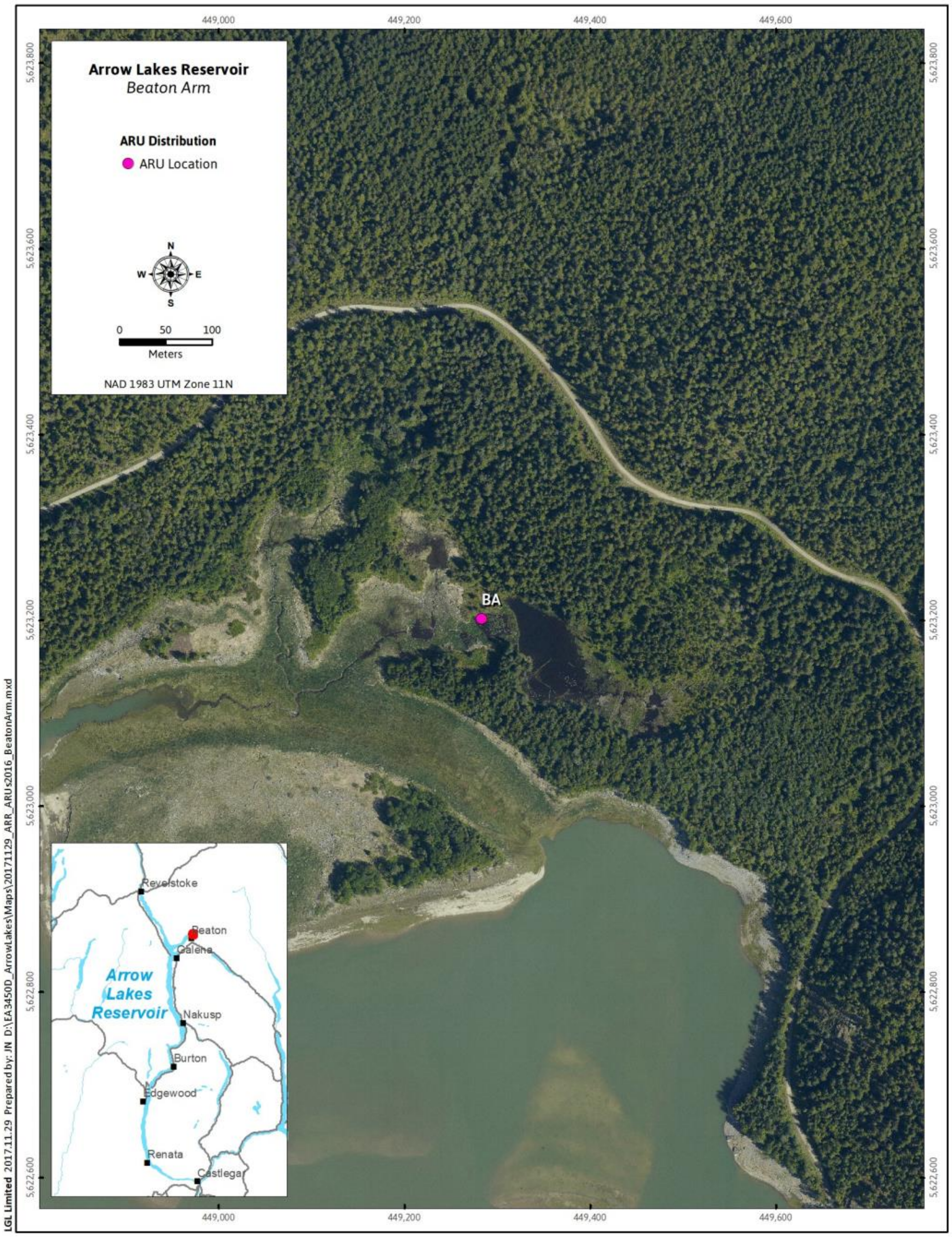
Map 11: Location of bat detector units installed at Burton Creek, 2016



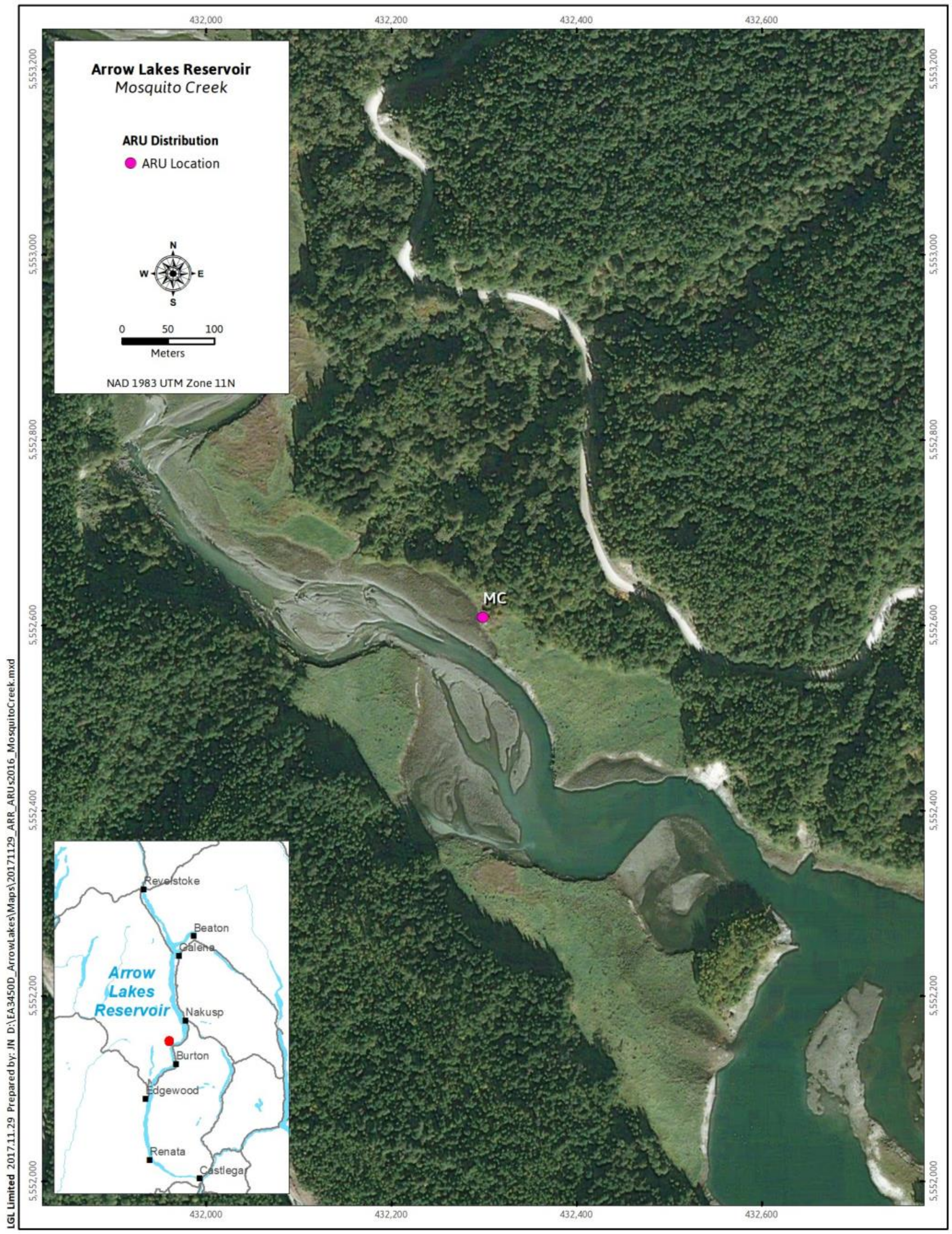
Map 12: **Location of bat detector units installed at Edgewood South, 2016**



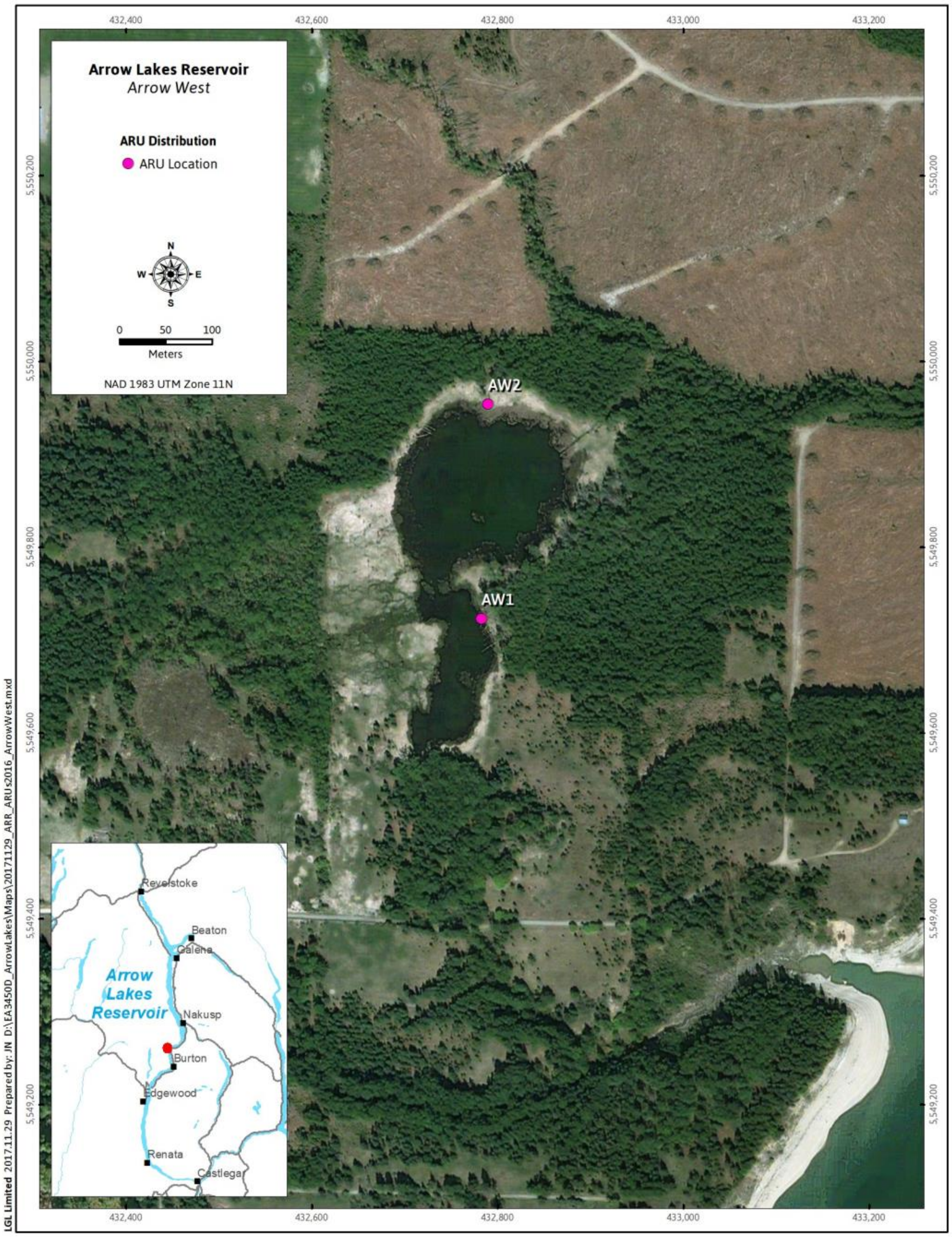
Map 13: Location of bat detector units installed at Lower Inonoaklin, 2016



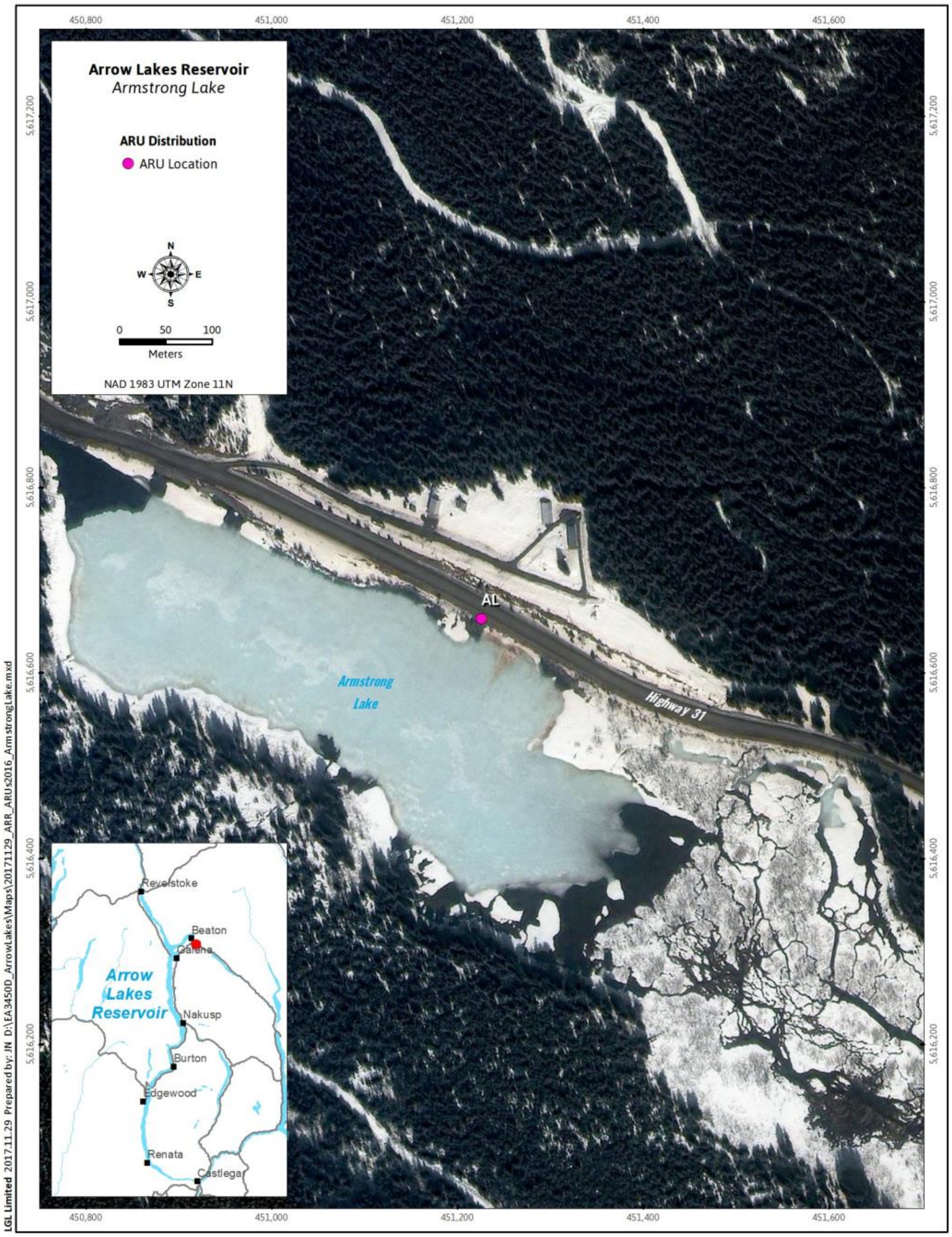
Map 14: Location of the bat detector unit installed at Beaton Arm, 2016



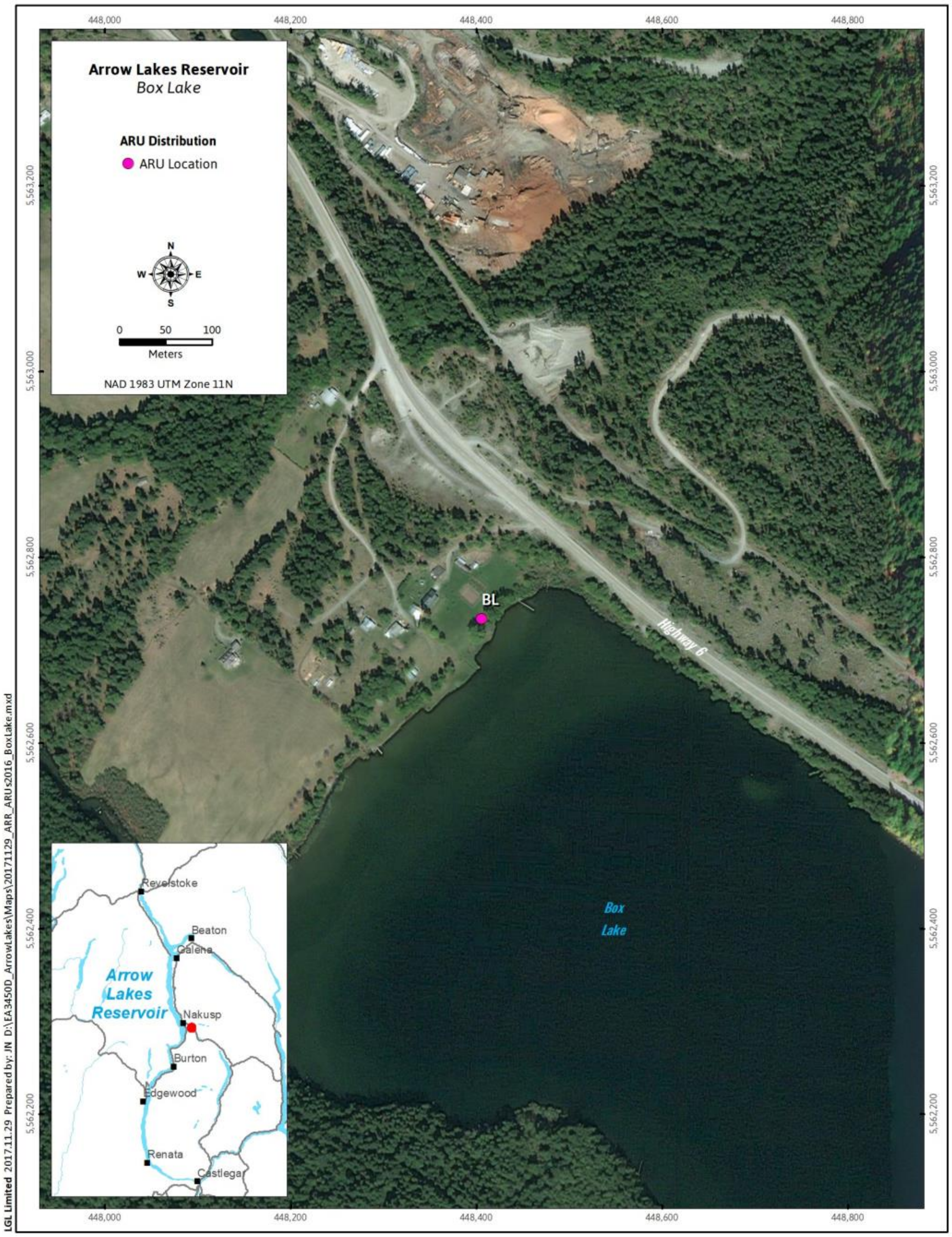
Map 15: Location of the bat detector unit installed at Mosquito Creek, 2016



Map 16: Location of the bat detector units installed at Arrow West (non-reservoir site), 2016



Map 17: **Location of the bat detector unit installed at Armstrong Lake (non-reservoir site), 2016**



Map 18: **Location of the bat detector unit installed at Box Lake (non-reservoir site), 2016**

Appendix D: Species Lists for the 2016 monitoring year

Table 9-1: List of bird species detected for the 2016 monitoring year. Species codes (Spp. Code) are given in alphabetical order with corresponding common names scientific names

Spp. Code	Common Name	Scientific Name
ALFL	Alder Flycatcher	*Empidonax alnorum*
AMCR	American Crow	*Corvus brachyrhynchos*
AMGO	American Goldfinch	*Spinus tristis*
AMKE	American Kestrel	*Falco sparverius*
AMPI	American Pipit	*Anthus rubescens*
AMRE	American Redstart	*Setophaga ruticilla*
AMRO	American Robin	*Turdus migratorius*
AMWI	American Wigeon	*Anas americana*
ATTW	American Three-toed Woodpecker	*Picoides dorsalis*
BAEA	Bald Eagle	*Haliaeetus leucocephalus*
BAGO	Barrow's Goldeneye	*Bucephala islandica*
BASW	Barn Swallow	*Hirundo rustica*
BBWO	Black-backed Woodpecker	*Picoides arcticus*
BCCH	Black-capped Chickadee	*Poecile atricapillus*
BEKI	Belted Kingfisher	*Megaceryle alcyon*
BHCO	Brown-headed Cowbird	*Molothrus ater*
BHGR	Black-headed Grosbeak	*Pheucticus melanocephalus*
BKSW	Bank Swallow	*Riparia riparia*
BLSW	Black Swift	*Cypseloides niger*
BOGU	Bonaparte's Gull	*Chroicocephalus philadelphia*
BRBL	Brewer's Blackbird	*Euphagus cyanocephalus*
BRCR	Brown Creeper	*Certhia americana*
BUFF	Bufflehead	*Bucephala albeola*
BUOR	Bullock's Oriole	*Icterus bullockii*
BWTE	Blue-winged Teal	*Anas discors*
CAFI	Cassin's Finch	*Haemorhous cassinii*
CAGO	Canada Goose	*Branta canadensis*
CAGU	California Gull	*Larus californicus*
CAHU	Calliope Hummingbird	*Selasphorus calliope*
CATE	Caspian Tern	*Hydroprogne caspia*
CAVI	Cassin's Vireo	*Vireo cassinii*
CBCH	Chestnut-backed Chickadee	*Poecile rufescens*
CCSP	Clay-colored Sparrow	*Spizella pallida*
CEWA	Cedar Waxwing	*Bombycilla cedrorum*
CHSP	Chipping Sparrow	*Spizella passerina*
CITE	Cinnamon Teal	*Anas cyanoptera*
CLNU	Clark's Nutcracker	*Nucifraga columbiana*
CLSW	Cliff Swallow	*Petrochelidon pyrrhonota*
COGO	Common Goldeneye	*Bucephala clangula*
COLO	Common Loon	*Gavia immer*
COME	Common Merganser	*Mergus merganser*
CONI	Common Nighthawk	*Chordeiles minor*
CORA	Common Raven	*Corvus corax*
COYE	Common Yellowthroat	*Geothlypis trichas*
DCCO	Double-crested Cormorant	*Phalacrocorax auritus*
DEJU	Dark-eyed Junco	*Junco hyemalis*
DOWO	Downy Woodpecker	*Picoides pubescens*
DUCK	Scaup sp.	*Aythya sp.*
DUFL	Dusky Flycatcher	*Empidonax oberholseri*
EAKI	Eastern Kingbird	*Tyrannus tyrannus*

Spp. Code	Common Name	Scientific Name
ECDO	Eurasian Collared-Dove	*Streptopelia decaocto*
EUST	European Starling	*Sturnus vulgaris*
EUWI	Eurasian Wigeon	*Anas penelope*
EVGR	Evening Grosbeak	*Coccothraustes vespertinus*
GADW	Gadwall	*Anas strepera*
GBHE	Great Blue Heron	*Ardea herodias*
GCKI	Golden-crowned Kinglet	*Regulus satrapa*
GHOW	Great Horned Owl	*Bubo virginianus*
GRCA	Gray Catbird	*Dumetella carolinensis*
GRJA	Gray Jay	*Perisoreus canadensis*
GRYE	Greater Yellowlegs	*Tringa melanoleuca*
GULL	Gull sp.	*Larus sp.*
GWFG	Greater White-fronted Goose	*Anser albifrons*
GWTE	Green-winged Teal	*Anas crecca*
HADU	Harlequin Duck	*Histrionicus histrionicus*
HAFL	Hammond's Flycatcher	*Empidonax hammondii*
HAWO	Hairy Woodpecker	*Picoides villosus*
HEGU	Herring Gull	*Larus argentatus*
HETH	Hermit Thrush	*Catharus guttatus*
HOFI	House Finch	*Haemorhous mexicanus*
HOGR	Horned Grebe	*Podiceps auritus*
HOLA	Horned Lark	*Eremophila alpestris*
HOME	Hooded Merganser	*Lophodytes cucullatus*
KILL	Killdeer	*Charadrius vociferus*
LALO	Lapland Longspur	*Calcarius lapponicus*
LBCU	Long-billed Curlew	*Numenius americanus*
LBDO	Long-billed Dowitcher	*Limnodromus scolopaceus*
LEFL	Least Flycatcher	*Empidonax minimus*
LESA	Least Sandpiper	*Calidris minutilla*
LESC	Lesser Scaup	*Aythya affinis*
LISP	Lincoln's Sparrow	*Melospiza lincolnii*
LZBU	Lazuli Bunting	*Passerina amoena*
MACW	MacGillivray's Warbler	*Geothlypis tolmiei*
MALL	Mallard	*Anas platyrhynchos*
MERL	Merlin	*Falco columbarius*
MGNW	Magnolia Warbler	*Setophaga magnolia*
MOBL	Mountain Bluebird	*Sialia currucoides*
MODO	Mourning Dove	*Zenaida macroura*
NAWA	Nashville Warbler	*Oreothlypis ruficapilla*
NOFL	Northern Flicker	*Colaptes auratus*
NOGO	Northern Goshawk	*Accipiter gentilis*
NOHA	Northern Harrier	*Circus cyaneus*
NOSL	Northern Shoveler	*Anas clypeata*
NOWA	Northern Waterthrush	*Parkesia noveboracensis*
NRWS	Northern Rough-winged Swallow	*Stelgidopteryx serripennis*
OCWA	Orange-crowned Warbler	*Oreothlypis celata*
OSFL	Olive-sided Flycatcher	*Contopus cooperi*
OSPR	Osprey	*Pandion haliaetus*
PALO	Pacific Loon	*Gavia pacifica*
PAWR	Pacific Wren	*Troglodytes pacificus*

Spp. Code	Common Name	Scientific Name
PBGR	Pied-billed Grebe	*Podilymbus podiceps*
PISI	Pine Siskin	*Spinus pinus*
PIWO	Pileated Woodpecker	*Dryocopus pileatus*
PSFL	Pacific-slope Flycatcher	*Empidonax difficilis*
RBGU	Ring-billed Gull	*Larus delawarensis*
RBNU	Red-breasted Nuthatch	*Sitta canadensis*
RCKI	Ruby-crowned Kinglet	*Regulus calendula*
RECR	Red Crossbill	*Loxia curvirostra*
REDH	Redhead	*Aythya americana*
REVI	Red-eyed Vireo	*Vireo olivaceus*
RNDU	Ring-necked Duck	*Aythya collaris*
RNGR	Red-necked Grebe	*Podiceps grisegena*
RNSA	Red-naped Sapsucker	*Sphyrapicus nuchalis*
RTHA	Red-tailed Hawk	*Buteo jamaicensis*
RUGR	Ruffed Grouse	*Bonasa umbellus*
RUHU	Rufous Hummingbird	*Selasphorus rufus*
RWBL	Red-winged Blackbird	*Agelaius phoeniceus*
SAVS	Savannah Sparrow	*Passerculus sandwichensis*
SESA	Semipalmated Sandpiper	*Calidris pusilla*
SOSA	Solitary Sandpiper	*Tringa solitaria*
SOSP	Song Sparrow	*Melospiza melodia*
SPSA	Spotted Sandpiper	*Actitis macularius*
SPTO	Spotted Towhee	*Pipilo maculatus*
SSHA	Sharp-shinned Hawk	*Accipiter striatus*
STJA	Steller's Jay	*Cyanocitta stelleri*
SWSP	Swamp Sparrow	*Melospiza georgiana*
SWTH	Swainson's Thrush	*Catharus ustulatus*
TOSO	Townsend's Solitaire	*Myadestes townsendi*
TOWA	Townsend's Warbler	*Setophaga townsendi*
TRSW	Tree Swallow	*Tachycineta bicolor*
TUVU	Turkey Vulture	*Cathartes aura*
UNSW	Unidentified Swallow	*Hirundidae (gen, sp)*
UNWO	Woodpecker sp.	*Picadae (gen, sp)*
VASW	Vaux's Swift	*Chaetura vauxi*
VATH	Varied Thrush	*Ixoreus naevius*
VEER	Veery	*Catharus fuscescens*
VGSW	Violet-green Swallow	*Tachycineta thalassina*
WAVI	Warbling Vireo	*Vireo gilvus*
WCSP	White-crowned Sparrow	*Zonotrichia leucophrys*
WEGR	Western Grebe	*Aechmophorus occidentalis*
WEKI	Western Kingbird	*Tyrannus verticalis*
WEME	Western Meadowlark	*Sturnella neglecta*
WETA	Western Tanager	*Piranga ludoviciana*
WIFL	Willow Flycatcher	*Empidonax traillii*
WIPH	Wilson's Phalarope	*Phalaropus tricolor*
WISN	Wilson's Snipe	*Gallinago delicata*
WIWA	Wilson's Warbler	*Cardellina pusilla*
WODU	Wood Duck	*Aix sponsa*
WTSP	White-throated Sparrow	*Zonotrichia albicollis*
WWCR	White-winged Crossbill	*Loxia leucoptera*

Spp. Code	Common Name	Scientific Name
WWPE	Western Wood-Pewee	*Contopus sordidulus*
YEWA	Yellow Warbler	*Setophaga petechia*
YHBL	Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*
YRWA	Yellow-rumped Warbler	*Setophaga coronata*

Table 9-2: **List of Orthoptera species detected for the 2016 monitoring year (both trap types).** Species codes (Spp. Code) are given with corresponding Family and Scientific names

Family	Scientific Name	Spp. Code
Acrididae	*Camnula pellucida*	Camn.pell
	Dissosteira carolina	Diss.caro
	Melanoplus bivittatus	Mela.bivi
	Melanoplus borealis	Mela.bore
	Melanoplus sanguinipes	Mela.sang
Gryllidae	*Allonemobius fasciatus*	Allo.fasc
Rhaphidophoridae	*Pristoceuthophilus celatus*	Pris.cela
Tetrigidae	*Tetrix subulata*	Tetr.subu
Tettigoniidae	*Conocephalus fasciatus*	Cono.fasc

Table 9-3: List of Araneae species detected for the 2016 monitoring year (both trap types). Species codes (Spp. Code) are given with corresponding Family and Scientific names

Family	Scientific Name	Spp. Code
Agelenidae	*Agelenopsis utahana*	Agel.utah
Clubionidae	*Clubiona moesta*	Club.moes
Corinnidae	*Castianeira walsinghami*	Cast.wals
Gnaphosidae	*Drassyllus depressus*	Dras.depr
	Gnaphosa muscorum	Gnap.musc
	Gnaphosa parvula	Gnap.parv
	Zelotes fratris	Zelo.frat
	Zelotes puritanus	Zelo.puri
Hahniidae	*Neoantistea agilis*	Neoa.agil
	Neoantistea magna	Neoa.magn
Linyphiidae	*Erigone aletris*	Erig.alet
	Erigone atra	Erig.atra
	Erigone blaesa	Erig.blae
	Erigone dentosa	Erig.dent
	Grammonota gentilis	Gram.gent
	Microlinyphia mandibulata	Micr.mand
	Oedothorax alascensis	Oedo.alas
	Walckenaeria directa	Walc.dire
	Walckenaeria exigua	Walc.exig
	Walckenaeria vigilax	Walc.vigi
Liocranidae	*Agroeca ornata*	Agro.orna
Lycosidae	*Pardosa altamontis*	Pard.alta
	Pardosa fuscula	Pard.fusc
	Pardosa mackenziana	Pard.mack
	Pardosa moesta	Pard.moes
	Pardosa xerampelina	Pard.xera
	Pirata piraticus	Pira.pira
	Trochosa terricola	Troc.terr
Philodromidae	*Tibellus oblongus*	Tibe.oblo
Phrurolithidae	*Phrurotimpus borealis*	Phru.bore
Tetragnathidae	*Tetragnatha laboriosa*	Tetr.labo
Theridiidae	*Enoplognatha marmorata*	Enop.marm
	Robertus vigerens	Robe.vige
Thomisidae	*Ozyptila sincera*	Ozyp.sinc
	Xysticus ferox	Xyst.fero

Table 9-4: List of arthropod families identified for the 2016 monitoring year (both Malaise and pitfall traps). Orders are given with corresponding Family

Order	Family	Order	Family	Order	Family
Coleoptera	Anthicidae	**Diptera**	Agromyzidae	**Hymenoptera**	Apidae
	Byrrhidae		Anthomyiidae		Bethylidae
	Carabidae		Anthomyzidae		Braconidae
	Chrysomelidae		Asilidae		Ceraphronidae
	Coccinellidae		Asteiidae		Chalcidae
	Corylophidae		Bibionidae		Charipidae
	Cryptophagidae		Bombyliidae		Chrysidiae
	Curculionidae		Calliphoridae		Crabronidae
	Dytiscidae		Cecidomyiidae		Cynipidae
	Elateridae		Ceratopogonidae		Diapriidae
	Hydrophilidae		Chamaemyiidae		Dryinidae
	Lampyridae		Chironomidae		Encyrtidae
	Latridiidae		Chloropidae		Eucoilidae
	Leiodidae		Chyromyiidae		Eulophidae
	Mycetophagidae		Clusiidae		Eupelmidae
	Nitiduliidae		Conopidae		Eurytomidae
	Ptiliidae		Culicidae		Figitidae
	Pyrochroidae		Diastatidae		Formicidae
	Scarabaeidae		Dolichopodidae		Halictidae
	Scraptiidae		Drosophilidae		Heloridae
	Silphidae		Dryomyzidae		Ichneumonidae
	Staphylinidae		Empididae		Megachilidae
	Throscidae		Ephydridae		Megaspilidae
	Trachypachidae		Heleomyzidae		Mymaridae
			Hybotidae		Perilampidae
			Lauxaniidae		Platygastridae
			Lonchaeidae		Pompilidae
			Micropezidae		Proctotrupidae
			Milichiidae		Pteromalidae
			Muscidae		Scelionidae
			Mycetophilidae		Sphecidae
			Odiniidae		Tenthredinidae
			Otitidae		Tiphidae
			Phoridae		Torymidae
			Pipunculidae		Trichogrammatidae
			Psilidae		Vespidae
			Psychodidae		Xiphydriidae
			Rhinophoridae		
			Sarchophagidae		
			Scatopsidae		
			Sciaridae		
			Sepsidae		
			Simuliidae		
			Sphaeroceridae		
			Syrphidae		
			Tabanidae		
			Tachinidae		
			Tipulidae		
			Ulidiidae		