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 8

Reference: CLBMON-11B1

Study Period: 2017

Okanagan Nation Alliance, Westbank, BC

and

LGL Limited environmental research associates
Sidney, BC

November 01, 2018

EA3450D

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 2017

Prepared for

BC Hydro Generation

Water Licence Requirements
6911 Southpoint Drive
Burnaby, BC

Prepared by

Charlene Wood[1], M.Sc., Nathan Hentze[1], M.Sc., Virgil C. Hawkes[1], M.Sc., R.P.Bio, and Jeremy Gatten[1], B.Sc.

[1]LGL Limited environmental research associates

and

Okanagan Nation Alliance

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

ONA Contact: David DeRosa; 1.250.687.4635

November 01, 2018

Suggested Citation:

Wood, C.M., N. Hentze, V.C. Hawkes, and J. Gatten. 2018. CLBMON-11B1. Kinbasket and Arrow Lakes Reservoirs: Wildlife Effectiveness Monitoring and Enhancement Area Identification for Lower and Mid-Arrow Lakes Reservoir. Annual Report – 2017. LGL Report EA3450. Unpublished report by Okanagan Nation Alliance, Westbank, B.C. and LGL Limited environmental research associates, Sidney, B.C., for BC Hydro Generation, Water Licence Requirements, Burnaby, BC. 57 pp. + Appendices.

Cover photos:

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) and wildlife physical works projects (i.e., those developed under CLBWORKS-29B and implemented under CLBWORKS-30), at enhancing the suitability of habitats in the drawdown zone of Arrow Lakes Reservoir for wildlife.

Revegetation work was conducted in the reservoir drawdown zone from 2008 to 2011 under the CLBWORKS-2 program. Various revegetation prescriptions were applied: two multi-species seed mixes applied by hydro-seeding or hand seeding, graminoid seeds planted by drill seeding or hand, graminoid seedlings planted by hand, shrub seedlings planted by hand, live stakes planted by excavator or hand, modified brush layers, and fertilizer spread by hand or ATV. By far, graminoid plug seedling treatments involving Kellogg's sedge (*Carex lenticularis* var. *lipocarpa*) dominated the planting regime. Results of CLBMON-12, an effectiveness monitoring study of the revegetation efforts, indicate that the revegetation program has met with mixed success to date (Miller et al. 2016, Miller et al. 2018).

Several potential wildlife physical works projects were developed under CLBWORKS-29B (Hawkes and Tuttle 2016, Hawkes and Howard 2012). A feasibility design was prepared for one location at Burton Flats under CLBWORKS-30B (Kerr Wood Leidel 2017). However, no wildlife physical works projects have been implemented to-date. Burton Flats will be the focus of future physical works effectiveness monitoring; though baseline data collection was initiated in 2017 through CLBMON-11B1.

To date, wildlife effectiveness monitoring under CLBMON-11B1 has occurred in years 2009, 2010, 2011, 2013, 2014, 2015, and 2016, making 2017 the eighth implementation year. This report which details the 2017 monitoring year, is the final report prepared under the original 2009 Terms of Reference for CLBMON-11B1. All future work will be guided by the Terms of Reference as revised in June, 2017.

The revegetation prescriptions applied in the drawdown zone may affect prey populations (i.e., terrestrial 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. The direction and magnitude of changes in arthropod populations are being tracked over time using two collection methods (pitfall traps and Malaise traps). Responses of birds are being monitored by point count surveys. Bat monitoring was conducted by deploying autonomous recording units. Bat presence and activity was then assessed by analyzing triggered bat call recordings using automatic classification software. The response of other taxa (i.e., amphibian, reptiles, western painted turtles, shorebirds, and waterfowl) to revegetation and wildlife physical works are being assessed under other studies. These data will serve as a metric to assess the efficacy of revegetation prescriptions and future habitat enhancements applied in the drawdown zone.

In 2017, wildlife monitoring occurred mainly within three sites with revegetation treatments: Burton Creek, Lower Inonoaklin, and Edgewood South. Arthropod, birds, and bats were all monitored at these sites. Bird point counts and nest searches were also conducted at Edgewood North, and in Revelstoke Reach at three new locations to this program: McKay Creek, 8-mile, and Drimmie Creek.

Within each site, sampling areas were classified as follows (collectively termed "habitat types"):

1. Reference. Above the drawdown zone, sampling was conducted in "reference" areas that were established upland of the reservoir (> 440.1 m ASL) to serve as non-reservoir drawdown zone controls. These are monitored to assess regional and natural variation in the taxa being studied.

   The remaining three sampling areas occur within the reservoir drawdown zone (i.e., at elevations below the normal operating maximum; ≤ 440.1 m ASL)

2. Treatment. The area of the drawdown zone that was revegetated using one of seven revegetation prescriptions developed for CLBWORKS-2. These treatments were delineated in polygons.

3. Control. 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.

4. Drawdown. Drawdown zone sampling areas were similar to controls, but occurred in areas without revegetation prescriptions. The pre-treatment sampling of Wildlife Physical Works areas is classified as drawdown zone.

Revegetation effectiveness monitoring results

Arthropods. Across sites, revegetation treatment and control polygons had similar arthropod composition, species richness, and biomass, indicating that treatment areas are not providing different habitat quality than adjacent control areas in the drawdown zone. Ground-dwelling spider communities were related to site attributes and vegetation parameters at treatment and select control polygons (where CLBMON-12 vegetation data coincided with trap locations). The Lower Inonoaklin treated habitat was associated with one unique spider species (*Walckenaeria vigilax*), as well as high soil moisture and herb cover. Edgewood South treatment was characterised by three spider species (*Neoantistea magna, Phidippus clarus, Castianeira walsinghami*), higher cover of live stakes, mineral soil, and rocky substrate. The two treatments at Burton Creek (BU01 and BU02) were very similar in terms of species composition, dominated by *Gnaphosa parvula* and *Xysticus ferox*, both open-habitat ground running spiders that do not require vegetation for prey capture.

Songbirds. Across years, several species of birds were observed directly utilizing revegetation treatments for foraging, nesting, and post-fledging. Nests of American Robin and Chipping Sparrow were in planted cottonwood stakes at Lower Inonoaklin in 2016, while Chipping Sparrow and Willow Flycatcher were in cottonwoods at Edgewood South in 2017. These observations confirm that birds respond to revegetation treatments, notably cottonwood stakes, where successful. Both ground-nesting and shrub- and tree-nesting species were documented from most surveyed sites, with most nests outside of revegetation polygons.

There was broad overlap in bird communities among treatment, control, and drawdown zone stations within Arrow Lakes Reservoir, and there was no discernible trend in bird communities related to revegetation treatments. Inter-annual variation in richness and diversity was considerable, and there was no evidence of a trend over time.

Bats. 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 (*Corynorhinus townsendii*), Western Small-footed Myotis (*Myotis ciliolabrum*), Northern Myotis (*M. septentrionalis*), Fringed Myotis (*M. thysanodes*), and Little Brown Myotis (*M. lucifugus*). The number of bat recordings per detector-hour (as a measure of relative activity) was highest at the upland reference site at Box Lake, followed by Arrow West. However, within study sites, data varied considerably in terms of relative abundance of each species. One rare bat species, Western Small-footed Myotis potentially occurred at Edgewood South.

Bat detectors in revegetation treatment and control areas at Edgewood South and Lower Inonoaklin were similar in terms of total bat activity. However, species-specific patterns were variable. For example, California Myotis (*M. yumanensis*) had much greater activity at one of the Lower Inonoaklin treatment detectors than any other sampling locations in the drawdown zone.

Wildlife Physical Works monitoring. Spring and fall waterfowl monitoring conducted at Burton Creek indicate the presence of up to 40 species of birds including 12 species of waterfowl, two grebes, and six species of gulls and shorebirds. However, none of these species were observed to be using the physical works site in the spring or fall, primarily because the reservoir elevation was <435 m ASL. It is anticipated that the creation of wetlands at the proposed physical works site will enhance the suitability of the drawdown zone for waterfowl, shorebirds, and gulls.

In addition to waterfowl, other species of wildlife (arthropods, songbirds, and bats) were monitored at the proposed physical works location. Collectively, these data are starting for form a suitable baseline of wildlife use that can be compared to data collected following the completion of the physical works.

Pre-treatment arthropod relative abundance, biomass, and spider species richness of WPW locations (BUN, BUS, and LI) were similar to adjacent drawdown zone revegetation treatments and control areas, suggesting that they are representative of the overall drawdown zone habitats.

Summary. Between 2009 and 2017, CLBMON-11B1 has monitored the effectiveness of revegetation treatments applied in the drawdown zone of Arrow Lakes Wildlife and wildlife use of those treatments. There is evidence that revegetation treatments are used by breeding birds; however, it has been challenging to demonstrate changes in the abundance and diversity of any of the focal groups, including birds.

As discussed in previous reports, there were several challenges associated with CLBMON-11B1 that made it difficult to answer the management questions. This reality was mitigated through the revision of the Terms of Reference for the CLBMON-11B projects in June 2017. The 2017 Terms of Reference will guide future work, but our ability to answer the management questions associated with CLBMON-11B1 following work completed in 2017, and based on the 2009 Terms of Reference, is provided below.

MQ	Able to Address MQ?	Scope: Current supporting results	Scope: Suggested modifications to methods where applicable	Sources of Uncertainty/Limitations
1. Are the revegetation and the wildlife physical works projects effective at enhancing wildlife habitat in the drawdown zone?	Inconclusive	There is evidence of species-specific responses to revegetated areas for some spider species but results for other taxa are inconclusive. The data do indicate that wildlife are using all habitat types, but current results show little difference between control and treatment plots. Physical Works: Unknown.	• Refocus the study to sample across a gradient of revegetation treatment success. Use data from CLBMON-12 (Miller et al. 2018) and CLBMON-35 (Adama et al. 208, draft) to select sites and increase replication. Pair treatment sites with untreated sites to compare metrics of wildlife use. • Include waterfowl and shorebirds as a focal taxa, particularly at proposed physical works sites. • Where applicable, utilize data collected under other programs (e.g., CLBMON-11B2 and 36) to augment data collected under CLBMON-11B1). • Continue to collect Conduct pre-treatment sampling prior to physical works implementation for all taxa (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 • 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?	Inconclusive	Revegetation treatments: 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. Physical Works: Unknown.	• See above	• See above
3. Are some methods or techniques more effective than others at enhancing wildlife habitat in the drawdown zone?	Inconclusive	Revegetation treatments: 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. A review of revegetation treatments is available in Miller et al. (2018) and should be incorporated into assessments of wildlife habitat suitability in the drawdown zone of Arrow Lakes Reservoir. Physical Works: Unknown.	• See above • A review of revegetation treatments is available in Miller et al. (2018) and should be incorporated into assessments of wildlife habitat suitability in the drawdown zone of Arrow Lakes Reservoir	• See above

Work in 2017 was based on the original Terms of Reference (BC Hydro 2009). In 2017, the Terms of Reference for CLBMON-11B1 were revised. As such, this 2017 annual report marks the final year of implementation of CLBMON-11B1 under the 2009 Terms of Reference.

Future work under CLBMON-11B1 will be based on the revised Terms of Reference, which requires changes to both the focus of the program and the study design. The proposed changes to the methods are not materially different than those used between 2009 and 2017.

In this report we make recommendations, in accordance with the revised TOR, which focus the assessment of wildlife use in an increased number of revegetation treatment polygons to better assess revegetation effectiveness in enhancing the suitability wildlife habitat in the drawdown zone.

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

ACKNOWLEDGEMENTS

The authors express their appreciation to the following individuals for their assistance in coordinating and conducting this study: Harry van Oort, Mark Sherrington, and Susan Pinkus (BC Hydro); Lisa Wilson, David DeRosa, Dixon Terbasket, Dave Tom, Sarah Alexis, Saul Sasquin, and Michael Dunn (Okanagan Nation Alliance); Dr. Robb Bennett, James Miskelly, Claudia Copley, and Dr. Joel Gibson (Royal British Columbia Museum); Bonnie Zand (Bonnie's Bugs IPM); Michael Miller, Doug Adama, Bryce McKinnon, Steven Roias, and Julio Novoa (LGL Limited), Devon Anderson, Gary Davidson, and Julia Burger (subcontracted by LGL Limited).

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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 revegetation treatment areas, from north to south, are shown in Figure 3-1. Wildlife effectiveness monitoring in 2017 focused on 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 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 or in proposed Wildlife Physical Works (WPW) locations. These data contribute to baseline data, should treatments be applied and 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 following projects to enhance wildlife habitat in the Arrow Lakes Reservoir, in lieu of maintaining lower reservoir levels:

1) A revegetation program to increase vegetation growth in the drawdown zone (CLBWORKS-2).
2) A study to evaluate the feasibility of enhancing or creating wildlife habitat in the drawdown zone in Revelstoke Reach (CLBWORKS-29A).
3) A study to identify high-value wildlife habitat sites for enhancement or protection in the Mid and Lower Arrow Lakes Reservoir (CLBWORKS-29B).
4) CLBWORKS-30: The implementation of wildlife physical works identified in CLBWORKS-29A and CLBWORKS 29B.

Revegetation was implemented in the drawdown zone of Arrow Lakes Reservoir under CLBWORKS-2 during years 2008 to 2011. South of Revelstoke Reach, options for wildlife enhancement strategies were developed under CLBWORKS-29B (Hawkes and Howard 2012, Hawkes and Tuttle 2016). Wildlife physical works identified in CLBWORK-29B will be implemented under CLBWORKS-30B.

This report outlines monitoring and results of CLBMON-11B1 in 2017[1], which focus on revegetation treatments (CLBWORKS-2) as wildlife physical works projects have yet to be implemented under CLBWORKS-30B.

2.0 OBJECTIVES AND MANAGEMENT QUESTIONS

CLBMON-11B1 is the first module in a suite of related effectiveness monitoring studies in the Arrow Lakes Reservoir, all of which were developed under one common CLBMON-11B Terms of Reference (TOR) in 2009. The Objectives, Management Questions, and Management Hypotheses listed in the 2009 TOR consider the entire suite of CLBMON-11B modules; some of the Management Hypotheses in the 2009 TOR do not apply to all modules equally.

The combined objectives of the overarching CLBMON-11B program, as defined in the 2009 Terms of Reference, were as follows:

1. Develop a monitoring program to assess the effectiveness of the revegetation program (CLBWORKS-2) and wildlife physical works projects

[1] CLBWORKS-30A implemented physical works in Revelstoke Reach. The efficacy of that program was monitored under other CLBMON-11B modules (11B2 through 11B5)

(CLBWORKS-30) in enhancing wildlife habitat in the drawdown zone of Arrow Lakes Reservoir.

2. Monitor the appropriate biological indicators and response variables to assess the effectiveness of the revegetation and wildlife physical works programs 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. Use this information to inform and improve enhancement techniques over time.

2.1 Management Questions

The Management Questions included in the overarching CLBMON-11B program, as defined in the 2009 Terms of Reference, were as follows:

1. Are the revegetation and the wildlife physical works projects effective at enhancing wildlife habitat in the drawdown zone?
2. If so, 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 2009 TOR lists Management Hypotheses to guide how Management Questions are addressed (see the Executive Summary, or Table 6.1 in Discussion).

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 effective in enhancing wildlife habitat. 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).

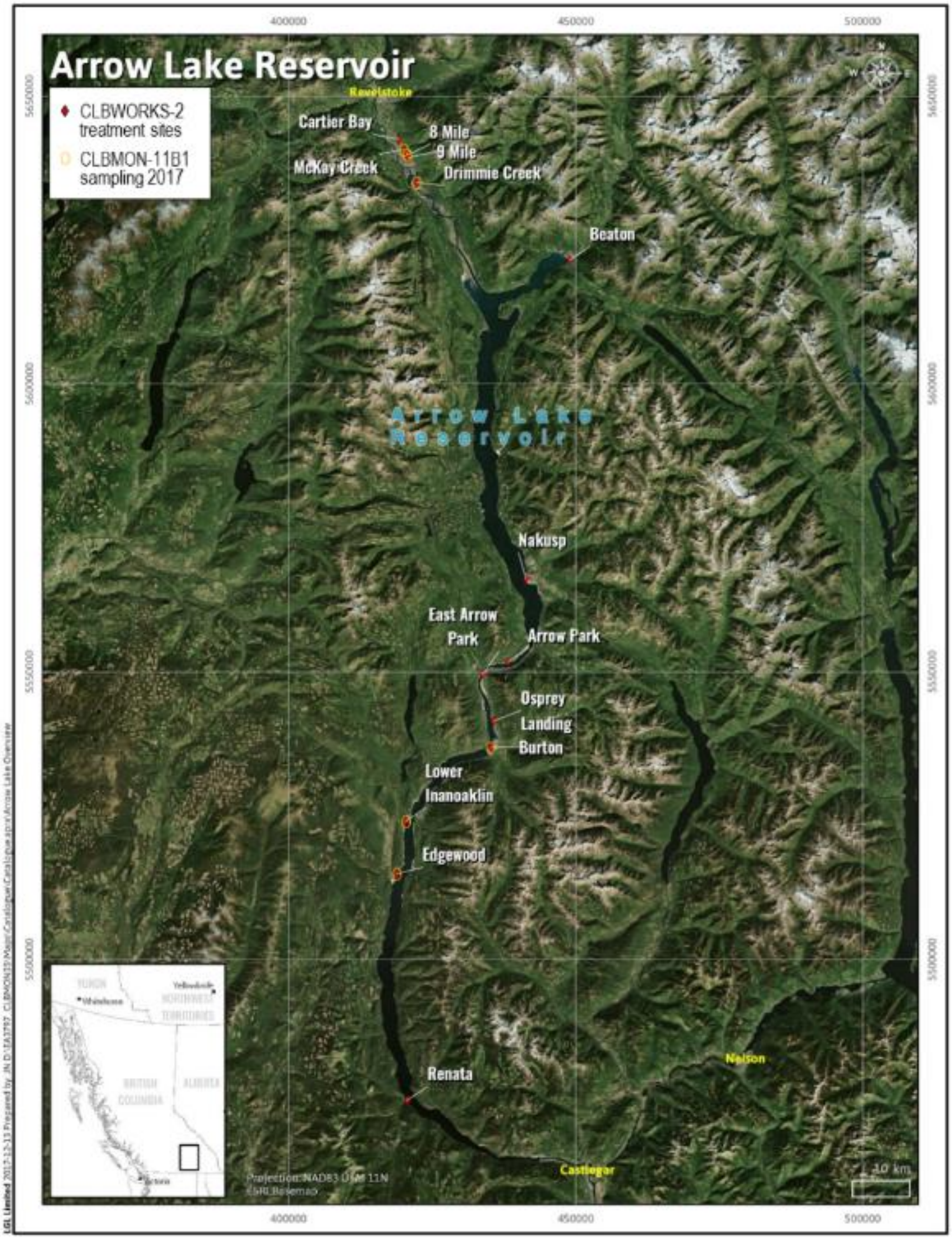

Figure 3-1: Location of revegetation treatment sites and 2017 wildlife monitoring sites within Arrow Lakes Reservoir in B.C. Note: only birds were surveyed at McKay Creek, 8-mile, and Drimmie Creek.

Since 2009, site selection was based on areas treated under CLBWORKS-2 (Keefer et al. 2009). Starting in 2017, sampling also occurred at sites where potential wildlife enhancement projects were being considered for development under CLBWORKS-30B and at select revegetation areas in Revelstoke Reach (birds only). Thus, only some sites were monitored annually and not all focal taxa were sampled at all sites (Table 3-1).

Table 3-1: List of sites sampled in each year from 2009 to 2017. "X": all taxa were sampled; "O": songbird surveys only; "-": no sampling occurred. Type: R = Revegetation, P = Physical Works; D = Drawdown zone. Note: sampling for bats is not reflected in this table

Site Name	Type	2009	2010	2011	2013	2015	2016	2017
Edgewood South	R/P	X	X	X	X	X	X	X
Edgewood North	R	X	X	X	X	X	O	O
Lower Inonoaklin	R/P	-	-	O	O	O	X	X
Burton Creek	R/P	X	X	X	X	X	X	X
East Arrow Park	R	X	X	X	X	-	O	-
Mosquito Creek	D	X	X	X	X	X	O	-
Beaton Arm	D	X	X	X	X	X	O	-
McKay Creek	R	-	-	-	-	-	-	O
8/9 Mile	R	-	-	-	-	-	-	O
Drimmie Creek	R	-	-	-	-	-	-	O

4.0 METHODS

4.1 Revegetation Treatments (CLBWORKS-2)

Revegetation treatment prescriptions applied under CLBWORKS-2 were monitored annually under CLBMON-12, with broad-scale assessments of most revegetation polygons conducted in 2017 (Miller et al. 2018). The Arrow Lakes Revegetation Catalogue (Adama et al. 2018, draft) summarizes the details of each revegetation prescription application and polygon locations.

We summarized revegetation prescriptions and surviving vegetation densities by site for the target treatment polygons sampled under CLBMON-11B1 in 2017, utilising information provided by Miller et al. (2018) and Adama et al. (2018, draft). This included the initial planting densities and 2017 vegetation densities for three broad revegetation types: graminoid seedling, shrub seedlings, and shrub stakes. Definitions are as follows:

Graminoid Seedling: Nursery grown seedlings of Kellogg's sedge (*Carex Kelloggii* var. *lipocarpa*), Columbia sedge (*Carex aperta*), water sedge (*Carex aquatilis*), wool-grass (*Scirpus atrocinctus*), small-flowered bulrush (*Scirpus microcarpus*), and bluejoint reedgrass (*Calamagrostis canadensis*) were hand planted by professional tree planting crews using planting shovels.

Shrub Seedling: Nursery grown seedlings of mountain alder (*Alnus incana*), black cottonwood (*Populus balsamifera*), chokecherry (*Prunus virginiana*), red-osier dogwood (*Cornus stolonifera*), wild rose (*Rosa acicularis*), and willow (*Salix* spp.) were hand planted by professional tree planting crews using planting shovels.

Shrub Stake: Live stakes of black cottonwood, red-osier dogwood, and willow (primarily Scouler's and Bebb's Willow) were either hand planted (HPL) or planted with the aid of a mini-excavator (EPL). Stakes were planted to depths of 30 to 50 cm with the aid of a planting bar to create a pocket for the stake.

4.2 Wildlife Physical Works (CLBWORKS-30B)

To date no projects have been implemented. Two have been designed (Lower Inonoaklin Road and Burton Creek wetlands), and one is planned (Burton Creek Wetlands). The physical works planned for Burton Creek include the creation of a series of tiered wetlands, mounding of soil to increase topographic heterogeneity, and a reed canarygrass removal trial (see Hawkes and Tuttle 2016). Following construction, the site will be revegetated using a combination of native plants (sedges, shrubs, and trees). The final construction plan for Burton Creek is expected later in 2018.

The proposed Burton Creek physical works location is located adjacent to Highway 6 from which it is highly visible, and accessible via Robazzo Road (Figure 4-1). The proposed project at Burton Creek will create ~2.8 ha of shallow wetland habitat through a combination of site excavation and dike construction. The elevation of the proposed physical works occurs between 437 and 440 m ASL. Over the past nine years, Arrow Lakes Reservoir has exceeded 437 m ASL between April 1 and October 31 for 0 (2015) to 141 days (2008). To reduce the potential for site inundation (and to promote the stability of the wetland habitat), the proposed dike will be ~390 m in length and a have a top elevation of 439 m ASL, which will be possible through the construction of a dike that varies in height from 50 to 180 cm. If built to an elevation of 439 m ASL, the dike will protect the created wetland from reservoir inundation for ~195 days per year (max: 214 days; min: 161 days based on a review of reservoir elevations recorded over the last nine years) assuming that wildlife will be most likely to use the constructed wetland between April 1 and October 31 (n=214 days). The project will improve wildlife habitat suitability through the creation of a currently limited habitat type (shallow wetland habitat) that is affected by reservoir operations or that was lost when upper and lower Arrow Lakes were impounded.

This construction is expected to benefit wildlife including birds, amphibians, reptiles, mammals (bats), insects (dragonflies) and fish. Species with provincial or federal conservation designation that will benefit from this project include the provincially blue-listed and COSEWIC species of Special Concern, Western Toad (*Anaxyrus boreas*); the provincially blue-listed Townsend's Big-eared Bat (*Corynorhinus townsendii*) and Fringed Myotis (*Myotis thysanodes*); and the COSEWIC endangered Little Brown Myotis (*Myotis lucifugus*) (listed February 27, 2012). The relatively homogeneous habitat that would be replaced with wetland habitat suggests little to no risk with this physical works. However, there is always a risk that the created habitat will not function as desired and require future interventions to increase productivity or habitat suitability for wildlife and vegetation.

Figure 4-1: Photograph of Burton Creek taken in spring 2010. The proposed location of the wildlife physical works in the drawdown zone of Arrow Lakes Reservoir is indicated as is the location of the private property. Caribou Creek and Burton Creek are shown in the top of the image. The existing lower elevation ponds are visible on the left side of the image. Reservoir elevation: 433.28 m ASL (date pf photo May 13, 2010).

With respect to wildlife effectiveness monitoring, baseline data are being collected at the physical works sites and data collected under other programs (e.g., CLBMON-37 and CLBMON-33) are available to describe current conditions. Current conditions as they pertain to wildlife are described in Hawkes and Tuttle (2016). In general, current wildlife habitat suitability is low and is expected to increase substantially with the implementation of the physical works.

4.3 Experimental Design

Different monitoring designs are used to test the efficacy of the spatially replicated revegetation treatments and the wildlife physical works to provide habitat for wildlife.

4.3.1 Revegetation monitoring design

To ensure that sampling was conducted entirely within areas where revegetation prescriptions were applied in the drawdown zone, we obtained shapefiles of the treatment polygons from Keefer Ecological Services in 2010. Because we wanted to compare treated areas to non-treated (or control) areas, we used the following approach to identity control and treatment polygons in each site where revegetation prescriptions were applied:

1. Using ArcMap 10, we selected the treatment polygon and created a copy of its size and shape.
2. The copied treatment polygon was placed in an area adjacent to the treatment polygon. The area selected for placement was similar in elevation, substrate type and vegetative cover. The newly created polygon became the control polygon.
3. Each treatment and control polygon was overlain with a 5-m^2 grid. Within each treatment and control polygon, we randomly selected grid cells for sampling. Cells were randomly selected for songbird and arthropod sampling (i.e., pitfall and malaise trapping).
4. The number of cells selected per treatment or control polygon was a function of polygon size. Where possible, a minimum of two songbird point count stations, five pitfall trapping locations and two malaise trap locations were selected within each control and treatment polygon.

An example of the layout described above is provided in Figure 4-2. Details of replicates are provided in the following taxon-specific sections.

Figure 4-2: Example of treatment and control area layout at Burton Creek. Treatments were applied by Keefer Ecological Services in 2009. Green circles represent songbird point count centres and blue circles represent the 30-m buffer around each point count. Orange = livestakes (hand planted); green = sedge plantings; pink = control polygons.

4.3.2 Wildlife Physical Works Monitoring Design

The efficacy of the physical works proposed for Burton Creek will be assessed using a Before-After assessment. The data collected to date represent the before period with data collection occurring in the physical works locations related to arthropods, birds (songbirds and waterfowl), bats, amphibian and reptiles, and vegetation. Large mammal use (e.g., ungulates) of the physical works location is based on opportunistic observations of wildlife and associated sign. Wildlife monitoring of the groups of wildlife will continue following completion of the physical works.

Data collection methods at the physical works location were the same as those used in to assess the effectiveness of revegetation treatments to provide habitat for wildlife. In addition to sampling for arthropods, songbirds and songbird nests, and bats, data were collected on the occurrence and distribution of waterfowl. Beginning in fall 2016, data on the distribution and occurrence of waterfowl were recorded from three locations (Edgewood, Lower Inonoaklin Road, and Burton Creek). In 2017, the same data were collected from Burton Creek. Sampling occurred weekly throughout the months of May and October. In October 2017, the weekly distribution and occurrence of all bird species using Burton Creek in the fall were mapped to provide an indication of the use of the area by birds during the fall migration period.

Additional baseline data relevant to the Burton Creek physical works site will be extracted from the CLBMON-37 database. All data collected to date under CLBMON-11B1 will be summarized to provide a summary of the base conditions as they pertain to wildlife. This update will occur in 2018 and will build on the summary in Hawkes and Tuttle (2016).

4.4 Response Measures

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.

4.4.1 Terrestrial Arthropods

Arthropods, including spiders and beetles, are the most diverse group of organisms found in terrestrial environments. Terrestrial arthropods are often abundant across many different ecosystems and habitats. A diversity of specialist species makes arthropods useful in monitoring studies because the respond rapidly to changes in the local and/or surrounding environment (McGeoch 1998; Schowalter 2006). Monitoring of ground-dwelling beetles (Carabidae and Staphylinidae) and spiders (Araneae) has been particularly useful for monitoring effects in other large-scale monitoring studies across Canada (Buddle et al. 2000, 2006; Buddle and Shorthouse 2008; Klimaszewski et al. 2008; Pinzon et al. 2012; Work et al. 2008, 2013) and elsewhere. Even a small number of sampling units and few individuals can reliably reflect community structure, allowing for cost-effective, efficient sampling (Blanchet et al. 2015).

In addition to being an important food source for many vertebrate taxa, such as birds, amphibians, and small mammals, terrestrial arthropods are integral to ecosystem processes such as decomposition, pollination, nutrient cycling, predation, and parasitism. Terrestrial arthropod abundance and diversity could be expected to increase with increasing vegetation structure and diversity (e.g., Humphrey et al. 1999; Söderström et al. 2001). Because of the trophic linkage between vegetation, arthropods, and songbirds, the inclusion of terrestrial arthropods as a focal species group to monitor makes intuitive sense. The potential for another selected focal species group (songbirds) to respond to changes in the composition and abundance of terrestrial arthropods resulting from the application of revegetation prescriptions provides the opportunity to identify direct and indirect effects of revegetation prescriptions on songbirds, which should be measurable over the course of this monitoring program.

Arthropod Sampling

Terrestrial arthropods were sampled at three main study sites in 2017: Burton Creek, Lower Inonoaklin, and Edgewood South. The target revegetation treatment polygons and trap locations are detailed in Appendix A.

Consistent with previous years (e.g., Hawkes et al. 2011, 2014, and 2018), arthropods were sampled via two trapping methods: pitfall trap arrays and Malaise traps. 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. This was done in GIS by first overlaying a 5 m x 5 m grid on the polygon and then randomly selecting each grid cell for sampling. New plots were selected each year.

One Malaise trap was installed in each control, treatment, drawdown zone, and reference habitat (where available). The number of samples at a given site thus varies based on the size and types of sampling areas present. Sampling locations were standardized between years and selected based on field topography and best practice methodologies outlined in provincial RIC standards (1998). Traps were filled with ~100 mL of preservation fluid (Propylene glycol, Univar Canada Ltd.) and checked daily to ensure functionality and record trap disturbance.

Sample Processing and Identification

Each trap location was used to generate two sample types: diversity samples (used for arthropod identification, relative abundance, relative richness, and composition) and biomass samples (used for measures of arthropod biomass). This was done by collecting each trap sample for use as a biomass sample, then replenishing collection fluid in each trap, and subsequently again collecting each trap sample for use as a diversity sample.

To align with previous monitoring years, we aimed to collect diversity and biomass samples in two collection periods. In some cases, only one collection could be made for some sampling points (e.g., Burton Creek and Lower Inonoaklin). In previous years collections were generally made in June and July, however, high reservoir elevations in 2017 precluded sampling in July, 2017, thus all arthropod collections were made during the month of June. The 2017 monitoring season generated a total of 252 samples, comprising 126 diversity samples and 126 biomass samples (Table 4-1).

Table 4-1: Number of arthropod samples collected for CLBMON-11B1 in 2017. Samples are a multiple of six due to five pitfall and one malaise sample per collection. Sites are abbreviated as: BU= Burton, LI= Lower Inonoaklin, and ES= Edgewood South. Habitat types are abbreviated as: R= upland reference, T= revegetation treatment, C= revegetation control, WPW= pre-treatment Wildlife Physical Works site.

	BU				ES			LI			Total
	R	T	C	WPW	R	T	C	T	C	WPW	
Collection 1											
Biomass	6	12	12	12	6	6	6	6	6	6	78
Diversity	6	12	12	12	6	6	6	6	6	6	78
Collection 2											
Biomass	6	12	12	12	6	6	6			6	48
Diversity	6	12	12	12	6	6	6			6	48
Total	24	48	48	48	24	24	24	12	12	24	**252**

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.

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. The biomass associated with each trap type, habitat type, site, and collection was kept separate for comparative purposes.

4.4.2 Birds

Monitoring the response of birds to management strategies has proven a pragmatic approach on several levels. For example, songbird monitoring can (1) measure the effectiveness of restoration and enhancement; (2) provide the necessary feedback for adaptive management; (3) guide restoration design by providing information on the health and habitat associations of the local bird populations; (4) be cost effective; and (5) provide education and outreach opportunities (Burnett et al. 2005). Because birds occupy an extremely diverse range of niches within an ecosystem and a relatively high position in the food chain, they are ideal indicators of environmental conditions (DeSante and Geupel 1987; Temple and Wiens 1989; Rich 2002). Along with the relative ease of study and the cost effectiveness of a songbird monitoring program, songbird monitoring provides researchers with feedback from a whole community of organisms, not just a single species. Thus, songbirds are a model organism for measuring the efficacy of restoration or enhancement projects.

Point Count Surveys

Time-constrained, variable-radius[2] point count surveys were used to assess the diversity and relative abundance of songbirds (Ralph et al. 1995). The number of point counts per year and habitat type (control, treatment, drawdown zone, and reference sites) varied by year (Appendix B). In total 161 point count stations were surveyed, with a maximum of 126 in any given year (Appendix B). The timing of the songbird surveys (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. 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).

Point count surveys were conducted at Reference points upland of the drawdown zone, and below the full-pool level of the reservoir at Control, Treatment, and Drawdown Zone stations. Treatment stations occurred within previously revegetation polygons, Control stations within non-revegetation areas at similar elevation bands as treatments, and Drawdown Zone stations within the drawdown zone but not within a paired treatment-control design.

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 during a 6-minute count period. 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), 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);
3. **Bird observations outside point count plots:** incidental observations of birds located outside the point count area at each site.

Nest Searches

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

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. Nest searches were not limited by taxa, though focused on songbirds and shorebirds.

4.4.3 Bats

There are potentially 12 bat species in the West Kootenays (Table 4-2). Live-capture studies have confirmed the presence of all those species except Western Small-footed Myotis (*Myotis ciliolabrum*). Five of these twelve species are of conservation concern at the provincial and/or national level (Table 4-2). In B.C., 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 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 a fungus caused by *Pseudogymnoascus destructans* that has been spreading westward since it was first documented in North America (COSEWIC 2013). Fringed Myotis is considered Data Deficient by COSEWIC, which means there is not enough scientific information available to support status designation.

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*	CORTOW	Yes	Blue		
Big Brown Bat	*Eptesicus fuscus*	EPTFUS	Yes	Yellow		
Hoary Bat	*Lasiurus cinereus*	LASCIN	Yes	Yellow		
Silver-haired Bat	*Lasionycteris noctivagans*	LASNOC	Yes	Yellow		
California Myotis	*Myotis californicus*	MYOCAL	Yes	Yellow		
Western Small-footed Myotis	*Myotis ciliolabrum*	MYOCIL	Unverified	Blue		
Long-eared Myotis	*Myotis evotis*	MYOEVO	Yes	Yellow		
Little Brown Myotis	*Myotis lucifugus*	MYOLUC	Yes	Yellow	Endangered	1-E (2014)
Northern Myotis	*Myotis septentrionalis*	MYOSEP	Yes	Blue	Endangered	1-E (2014)
Fringed Myotis	*Myotis thysanodes*	MYOTHY	Yes	Blue	Data Deficient	3 (2005)
Long-legged Myotis	*Myotis volans*	MYOVOL	Yes	Yellow		
Yuma Myotis	*Myotis yumanensis*	MYOYUM	Yes	Yellow		

To study bat presence and distribution over and adjacent to the drawdown zone, Wildlife Acoustics SM2BAT+ autonomous recording units were deployed from early June to late September in 2017. Each unit was programmed with a schedule to document bats during two periods: i) half an hour before sunset for 5.5 hours, and ii) an hour before sunrise for 1.5 hours, for a total of 7 hours per 24 hour period.

A total of fourteen bat detectors were deployed along the Arrow Lakes Reservoir. Location of each detector is provided in Appendix D. Four detectors were deployed in upland areas (>440.1 m ASL) to serve non-reservoir reference sites. These included: Armstrong Lake (n=1), Box Lake (n=1), and a natural wetland located at West Arrow (n=2). Within the drawdown zone, three detectors were deployed in each site at: Burton Creek, Edgewood South, and Lower Inonoaklin, with an additional detector deployed at Mosquito Creek (n=1).

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 approximately 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).

4.4.4 Wildlife Physical Works

Hawkes and Tuttle (2016) suggested the following performance measures to assess success of the physical works at Burton Creek:

1. Creation of at least 2.0 ha of new wetland habitat in an area dominated by grass species (i.e., no current wetland habitat).
    a. Temporal availability of wetland overlaps with the migratory bird (particularly wetland-associated species) and amphibian breeding seasons (May-August). The permanence of the wetland should be assessed (i.e., is the wetland available each year and for how long?)
    b. Minimum depth of pond required to support amphibian breeding and larval development (20 to 100 cm).
2. Wetland productivity:
    a. Successful establishment of native macrophytes (planted or natural) into newly created wetlands within five years. “Successful establishment” is defined here as continuous species presence for at least two years. Currently there are no macrophytes at the site proposed for physical works.
    b. Successful natural establishment of native macroinvertebrates (e.g., odonates, cladocerans, gastropods) into newly created wetlands within 5 years. “Successful establishment” is defined here as continuous species presence for at least two years. The current biomass of macroinvertebrates at this site is nil.
    c. Evidence of breeding by amphibians (specifically Western Toad). The number of egg strings or masses should be counted on an annual basis following the implementation of the physical works. Egg development should be tracked to determine if eggs metamorphose into froglets or toadlets. Western Toads currently breed in the ponds situated at elevations <434 m ALS, but do not breed at the site proposed for physical works.
    d. Evidence of use of the wetland by waterfowl and shorebirds. Waterfowl have been observed using the area proposed for physical works, but only when inundated by Arrow Lakes Reservoir. For example Mallard (*Anas platyrhynchos*), Barrow's Goldeneye (*Bucephala islandica*), and Common Merganser (*Mergus merganser*) were observed at the Burton Creek site in July 2016 (J. Gatten, LGL Limited Biologist, pers. obs.).
    a. Evidence of use of habitat enhancements (e.g., nest boxes, floating islands) by target waterfowl species (which will need to be determined) following completion of construction.

e. Evidence of use of the constructed wetland by bats (as determine by autonomous recording units) and use of enhancements such as bat boxes, snags, or other enhancements).

f. No reduction in the species composition of bats at the Burton Creek site, which currently includes up to nine species.

4.5 Data Analyses

In general, data analyses followed those performed in recent years (e.g., Hawkes et al. 2018; Hawkes et al. 2014). Most of the results reported summarize the data collected in 2017 and do not represent a detailed assessment of overall spatial/temporal trends.

4.5.1 Revegetation Treatments

Vegetation data were tabulated by site for the target treatment polygons sampled in 2017. CLBWORKS-2 prescriptions (Keefer and Moody, 2010; Keefer Ecological Services, 2010, 2011), initial planting densities, and current vegetation densities are summarized by transplant species for each revegetation type: graminoid seedling, shrub seedlings, and shrub stakes. Example photos are given for treatments at Edgewood South, Lower Inonoaklin, and Burton Creek. Data and photos provided from Adama et al. (2018, draft) and Miller et al. (2018). Survival density was calculated as the number of live stems per hectare recorded during the 2017 revegetation effectiveness monitoring (CLBMON-12).

4.5.2 Birds

Bird analyses were limited to passerines (e.g., songbirds, swallows), swifts, and hummingbirds. For ease of reading throughout the report we collectively refer to these as “songbirds”, and the majority of bird detections were indeed of true songbirds. We limit analyses to detections within 75 m of the point count centre (reference points), or 30 m of the point count centre (points within the drawdown zone, including treatment and control stations). Birds detected as fly-overs were 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. Maps depicting the location and distribution of songbird point count stations for each site and treatment sampled in 2017 are provided in

Appendix B: Number of point count stations by year, site, and habitat type.

C = Control, T = Treatment, DDZ = Drawdown Zone, R = Reference

Site	Treatment	Year							
		2009	2010	2011	2013	2015	2016	2017	Total
Beaton Arm	DDZ	5	5	5	7	5	4	0	7
	R	9	9	9	9	9	9	0	9
Burton Creek	C	5	7	7	7	6	6	6	7
	T	6	6	6	6	6	6	6	6
	DDZ	5	5	5	5	5	4	12	12
	R	6	9	6	9	9	9	9	9
East Arrow Park	C	9	9	9	9	0	3	0	9
	T	9	9	9	8	0	5	0	9
	DDZ	2	2	2	2	0	2	0	2
	R	11	11	10	13	0	7	0	13
Edgewood North	C	2	2	2	2	2	2	2	2
	T	3	4	4	4	4	4	4	4
	DDZ	2	2	2	2	2	2	2	2
	R	2	6	2	4	4	4	6	6
Edgewood South	C	3	3	3	3	3	3	3	3
	T	3	3	2	3	3	3	3	3
	DDZ	1	0	0	0	1	0	0	1
	R	6	6	6	6	6	6	6	6
Lower Inonoaklin	T	0	0	8	8	7	8	7	8
	DDZ	0	0	1	1	1	1	3	3
Mosquito Creek	DDZ	9	8	9	9	9	9	0	3
	R	9	8	9	9	9	9	0	3
McKay Creek	C	0	0	0	0	0	0	3	9
	T	0	0	0	0	0	0	3	9
12 Mile	C	0	0	0	0	0	0	4	4
	T	0	0	0	0	0	0	4	4
9 Mile	C	0	0	0	0	0	0	4	4
	T	0	0	0	0	0	0	4	4
Total	C	19	21	21	21	11	14	22	38
	T	21	22	29	29	20	26	31	47
	DDZ	24	22	24	26	23	22	17	30
	R	43	49	42	50	37	44	21	46
	Total	*107*	*114*	*116*	*126*	*91*	*106*	*91*	*161*

Appendix C.

Species richness and diversity analyses were completed for treatment, control and drawdown zone points, at sites that were surveyed in 2017 and had multiple years of data (Burton Creek, Edgewood South, and Edgewood North). Data were summarized by including only surveys from June and July, to ensure consistency among years. The maximum count of individuals per species for all visits to that station in a year was determined, such that one replicate equalled a particular point count station per year. That is, the statistical unit was the point count, which was replicated within habitats, sites, and years (Appendix B).

Richness (q) was calculated as the total number of songbird species detected per point count station. Diversity (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. Thus, species diversity similar to richness, though it accounts for both the abundance and evenness of the species present.

Species richness and diversity were compared among years, treatment types, and sites with boxplots.

Reference plots provide an indication of inter-annual variation in "stable" habitats (i.e., mature forests), that are less exposed to weather extremes and occur upland of reservoir activity (compared to habitats in the drawdown zone of reservoirs). All else being equal, we expect variation in reference plots to be minimal among years and suggestive of the latent inter-annual variation in climate and taxa under study. Thus, boxplots of species richness and diversity are produced to visualize annual trends in general bird populations and may help explain trends seen in the drawdown zone.

Species composition and assemblage similarity were assessed through ordinations and Permutational Multivariate Analysis of Variance (PERMANOVA) tests. The experimental unit for nonmetric multidimensional scaling (NMDS) ordinations was the habitat type. The method of pooling data was as described for richness and diversity, but abundance values were averaged over all years of surveying in a treatment per site (i.e., all the treatment sites Burton Creek were averaged to present a single data point for that site/treatment combination in the ordinations). Results of statistical tests were considered significant at α=0.10.

4.5.3 Terrestrial Arthropods

The total number of diversity and biomass samples from both trap types (Malaise and pitfall) used in all analyses are given in Table 4-1.

Relative abundance was calculated as catch-per-unit-effort (CPUE), equal to the number of arthropods caught per trap, standardized to a 24-hour trapping period (i.e., arthropods per trap-day). This data was generated from diversity samples only, as biomass samples were not sorted for arthropod abundance. Mean CPUE of Malaise traps was summarized in tabular format, due to low sample size (n=1 within each habitat type in each site per collection). Boxplot graphs were provided for mean CPUE of pitfall trap samples (n= 5 pitfalls in each habitat type, in each site, per collection).

Richness was standardized using sample-size-based Rarefaction/Extrapolation curves (Colwell et al. 2012; Chao et al. 2014). This type of sampling curve plots the species richness estimates with respect to sample size (e.g., number of individuals collected). Species richness curves were generated using the package 'iNEXT' in R (Hsieh et al. 2016). iNEXT uses the abundance data to compute diversity estimates and the associated bootstrapped 95% confidence intervals (plotted as a shaded region around curves).

Biomass was calculated as the dry weight of arthropods (mg) per trap-hour for each sample. Biomass values were assessed by site, trap type, and habitat with box plots. Data are presented for 2017 samples alone, as well as with samples pooled from 2015-2017.

Composition and similarity of assemblages were assessed with Venn diagrams using the package 'VennDiagram' in R (Chen 2015). These graphically display the number of unique species (or families) in treatment and control plots and the number of species that were shared between plots for arthropod sampling. The area of each ellipse is proportional to the total number of species observed for that habitat type. Families of Diptera and Hymenoptera are presented from Malaise trap data. Families of Coleoptera and species of Araneae are presented from pitfall trap data.

To extract and summarise the variation in spider species assemblages from 2015-2017, we conducted a redundancy analysis (RDA) with a set of explanatory variables extracted from vegetation data collected under CLBMON-12 (Miller et al. 2018). Only pitfall trap sampling locations that coincided with vegetation monitoring plots were included in the analysis, reducing the overall dataset to mostly treatment plots. Table 4-3 summarizes the arthropod samples included for this analysis. Explanatory data included in the analysis are summarized in Table 4-4. RDA is a canonical (constrained) ordination technique that relates two or more sets of data and formally tests statistical hypotheses about the significance of these relationships. In our case, one data set contains response variables: standardized abundances of each spider species in each sampling location, and one data set contains explanatory site/vegetation data. RDA is a direct extension of regression analysis to model multivariate response data. The statistical significance of the RDA (global model) was tested by 999 permutations. RDA was performed using the vegan package for community ecology (Oksanen et al. 2018) in the R language (R Core Team 2017).

Table 4-3: Samples included for RDA analysis of spider species community response to site conditions and vegetation Data from pitfall trap sampling in years 2015-2017.

Reach Name	Sampling Location	Year	Total Trap Hours	n pitfall samples
Burton Creek	BU01 T	2015	295.95	4
		2016	426.39	6
		2017	622.05	9
	BU02 T	2015	217.18	3
		2016	495.76	7
		2017	350.23	5
Edgewood South	ES T	2015	355.77	5
		2016	333.06	5
		2017	463.88	7
Lower Inonoaklin	LI C	2016	610.59	8
		2017	306.72	5
	LI T	2016	77.81	1
		2017	276.71	4

Table 4-4: Explanatory variables included for RDA analysis of spider species community response to site conditions and vegetation Data from CLBMON-12 vegetation monitoring in 2017 (Miller et al. 2018).

Variable	Type	Description
Year	Factor	2015, 2016, 2017
Reach	Factor	BU, ES, LI
Elevation	Numeric	Extracted from 2014 DEM
Slope	Numeric	Mean degrees from horizontal
Moisture	Numeric	Soil Moisture Regime: mean of class, ranging from 0 (Very Xeric) to 7 (Subhydric)
Rock (%)	Numeric	Mean per cent cover of surface substrate comprised of rock
Mineral (%)	Numeric	Mean per cent cover of surface substrate comprised of mineral soil
Organic (%)	Numeric	Mean per cent cover of surface substrate comprised of organic matter
Wood (%)	Numeric	Mean per cent cover of surface substrate comprised of wood debris
Herbs (%)	Numeric	Mean per cent cover of herbaceous vegetation
Shrubs (%)	Numeric	Mean per cent cover of shrubs
Graminoid Density	Numeric	Density of transplanted graminoid seedlings remaining since treatment
Live Stake Density	Numeric	Density of transplanted live stakes remaining since treatment

4.5.4 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 4-5; also, Szewczak *et al.* 2011a, b). Bat presence and activity was therefore assessed by analyzing triggered recordings from Wildlife Acoustics SM2BAT+ units using their proprietary automatic ID software, Kaleidoscope Pro v. 4.5.4. The software program is a quick and effective tool for analyzing 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 expected bat fauna in an area. The classifiers for 11 species that have been confirmed in the West Kootenays were selected for use in auto ID analysis of 2017 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 solely at Edgewood South (C. Lausen, PhD, Birchdale Ecological, 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 4-5: 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 recording period was investigated to see when bats were most active relative to sunrise and sunset. 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.

Bat species richness was summarized for each site. Data were pooled by site and the proportion of detections for each species was compared. 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.

To examine patterns in bat species assemblages in 2017, we performed Principal Components Analysis (PCA) using the Hellinger distance measure applied on standardized abundance (number of bat recordings per detector-hour). 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. Species that clustered around the plot centre were removed for clearer presentation. Ordination plots were provided for each PCA to show the relationships between taxa and samples. All ordinations were performed using the vegan package for community ecology (Oksanen et al. 2018) in the R language (R Core Team 2017).

5.0 RESULTS

5.1 Reservoir Conditions

Reservoir elevations in 2017 were lowest in January to February, hitting the lowest yearly point (427.15 m ASL) on February 5, 2017 (Figure 5-1). Water levels increased after that, peaking on July 28, 2016 (439.54 m ASL). Following peak reservoir elevation, water levels dropped steadily until December 4, 2017 (435.74 m ASL) at which time they increased again.

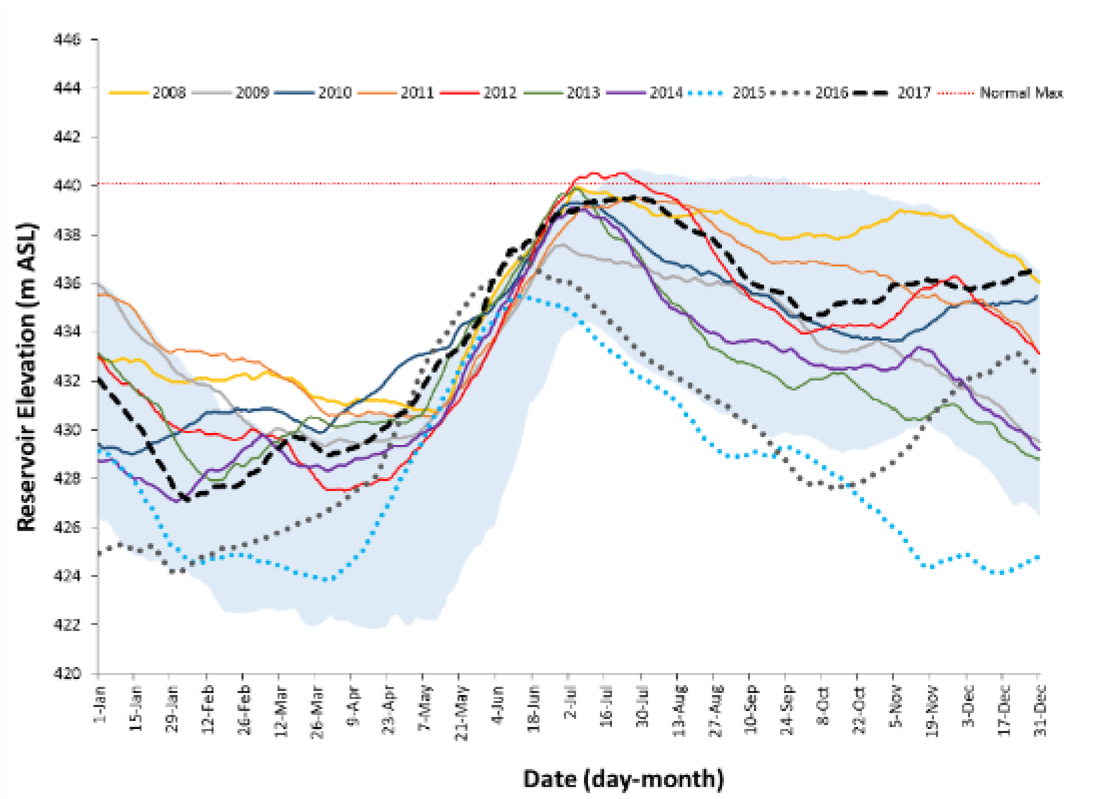

Figure 5-1: Arrow Lakes Reservoir elevations for 2008 to 2017. The 10th and 90th percentiles are shown for 1969-2017 (shaded area); m ASL= metres above sea level

5.2 Revegetation Treatments

The revegetation prescriptions and survival densities for the treatment polygons of interest in each study area are summarized in Table 5-1. Results indicated that transplant success was highly variable in the drawdown zone. Survivorship of sedge seedling plugs, shrub seedlings, and shrub live stakes ranged from zero (treatment failure) to 100 per cent (full survival) depending on site and polygon (Miller et al. 2018). In these select treatment polygons, there was 0 per cent survival for Willow live stakes (Burton, Lower Inonoaklin, and Edgewood South). Only 45 per cent of treatments contained some surviving stems of the transplant species, many with large decreases in density since planting (decreases in 16 out of 20 treatments; Table 5-1).

Table 5-1: Summary table of revegetation prescriptions and survivorship in treatment areas sampled under CLBMON-11B1 in 2017, listed from North to South. Source: Adama et al. (2018, draft) and Miller et al. (2018). Type Codes: HPL= hand-planted live stake, EPL= excavator-planted live stake, PS= sedge plug; '-' = vegetation not assessed. Vegetation trend: ↓= decrease in density since planting, ↑= increase in density since planting.

Study Site	Treatment Year	CLBWORKS-2 Polygon ID	Elevation (mASL)	Polygon Area (ha)	Treatment Type	Type Code	Species	Planting Density	Survival Density	Vegetation Trend
McKay Creek	2010	RR4_A	438.33	0.14	shrub stake	EPL	black cottonwood	1110 sph	0 sph	↓
McKay Creek	2010	RR4_B	438.40	0.20	shrub stake	EPL	black cottonwood	1049 sph	0 sph	↓
McKay Creek	2010	RR4_C	438.64	0.55	shrub stake	EPL	black cottonwood	1073 sph	533 sph	↓
8 Mile	2010	RR5_A	438.59	2.70	shrub stake	EPL	black cottonwood	924 sph	0 sph	↓
8 Mile	2010	RR5_A	438.59	2.70	shrub stake	EPL	Red-osier Dogwood	63 sph	0 sph	↓
Drimmie Creek	2010	RR9	438.01	2.17	shrub stake	EPL	black cottonwood	771 sph	967 sph	↑
Burton Creek	2009	25	439.07	1.22	shrub stake	EPL/HPL	black cottonwood	1109 sph	200 sph	↓
Burton Creek	2009	25	439.07	1.22	shrub stake	EPL/HPL	willow sp.	200 sph	0 sph	↓
Burton Creek	2009	25	439.07	1.22	shrub stake	EPL/HPL	Dogwood	51 sph	-	-
Burton Creek	2009	64	436.78	2.34	graminoid seedling	PS	mixed graminoid species	14026 sph	6600 sph	↓
Burton Creek	2009	65	436.35	0.74	graminoid seedling	PS	mixed graminoid species	14026 sph	11133 sph	↓
Lower Inonoaklin	2009	13	437.26	0.54	shrub stake	EPL	black cottonwood	2017 sph	2067 sph	↑
Lower Inonoaklin	2009	13	437.26	0.54	shrub stake	EPL	willow sp.	357 sph	0 sph	↓
Lower Inonoaklin	2009	16	437.49	0.18	shrub stake	EPL	black cottonwood	2017 sph	1300 sph	↓
Lower Inonoaklin	2009	16	437.49	0.18	shrub stake	EPL	willow sp.	357 sph	0 sph	↓
Edgewood (North)	2009	7	435.19	1.45	graminoid seedling	PS	mixed graminoid species	13159 sph	1950 sph	↓
Edgewood (South)	2009	3	437.71	0.65	shrub stake	EPL	Black Cottonwood	2425 sph	2533 sph	↑
Edgewood (South)	2009	3	437.71	0.65	shrub stake	EPL	Willow Sp.	800 sph	0 sph	↓
Edgewood (South)	2009	4	439.66	0.15	shrub stake	EPL	Black Cottonwood	2425 sph	0 sph	↓
Edgewood (South)	2009	4	439.66	0.15	shrub stake	EPL	Willow Sp.	800 sph	0 sph	↓

At Burton Creek, treatment polygon 25 had 200 sph of live cottonwood stakes remaining, whereas sedge plug densities varied within polygons 64 and 65 (Figure 5-2).

Figure 5-2: Examples of revegetation prescriptions trialed at Burton Creek. Left: cottonwood stakes, centre and right: sedge plugs. Photo credit: Mike Miller, 2017.

At Lower Inonoaklin, polygons 13 and 16 were treated with a mixture of cottonwood and willow live stakes. Only cottonwood stakes remained as of the 2017 CLBMON-12 monitoring year, ranging in density from 1300 sph to 2067 sph (Figure 5-2).

Figure 5-3: Examples of revegetation prescriptions trialed at Lower Inonoaklin. Left: successful cottonwood stakes; right: live stakes affected by wood debris deposition. Photo credit: Mike Miller, 2017.

At Edgewood South, live stake treatments exhibited mixed success (Figure 5-2), with polygon 3 containing 2533 sph of cottonwood in 2017, a slight increase in density since initial planting (Table 5-1). However, polygon 4 contained no surviving cottonwood or willow stakes in 2017.

Figure 5-4: Examples of revegetation prescriptions trialed at Edgewood South. Photos show variable success of live stake treatment. Photo credit: Mike Miller, 2017.

Factors limiting transplant establishment success included operational effects related to inundation regimes (e.g., erosion, deposition, wave scouring, wood debris scouring, and drought conditions) and non-operational effects (e.g. substrates, nutrients, rodent damage, ATV traffic, other human disturbances).

5.3 Arthropods

A total of 23,645 individual arthropods were collected in the 2017 diversity samples (excluding the vast numbers of Acari and Collembola that were not counted).

5.3.1 Relative abundance

Standardized arthropod abundance (number of arthropod individuals caught per trap, per 24-hour period) varied largely by trapping method with Malaise trapping yielding higher catch per unit effort (CPUE) than pitfall trapping (Table 5-2). Malaise trap samples were dominated by Diptera, Hymenoptera, and Lepidoptera (Appendix D; Figure 9-1), whereas pitfall trap samples were dominated by Araneae, Coleoptera, and Hemiptera (Appendix D; Figure 9-2). Results of Malaise trap abundance is hampered by a low sample size at each sampling location (i.e., $n \leq 2$), thus caution should be applied for interpretation of Malaise trap data.

Table 5-2: Mean arthropod catch per trap per day for Malaise and pitfall trap arrays by sampling location and habitat type. Means are shown in bold, n= number of diversity samples (i.e., trap collections not arrays; collections not pooled prior to averaging). T= revegetation treatment, C= drawdown zone control, WPW= wildlife physical works location, and R= non-drawdown zone reference.

		T		C		WPW		R	
		mean	*n*	**mean**	*n*	**mean**	*n*	**mean**	*n*
Malaise	BU							**324.3**	*2*
	BU01	**561.3**	*2*	**689.2**	*2*				
	BU02	**392.6**	*1*	**415.6**	*1*				
	BUN					**752.9**	*2*		
	BUS					**911.4**	*1*		
	ES	**1324.3**	*2*	**857.8**	*2*			**796.0**	*2*
	LI	**761.7**	*1*	**492.2**	*1*	**1601.4**	*2*		
Pitfall	BU							**14.8**	*10*
	BU01	**32.3**	*10*	**30.6**	*10*				
	BU02	**36.0**	*5*	**33.3**	*5*				
	BUN					**39.0**	*10*		
	BUS					**18.7**	*5*		
	ES	**18.2**	*10*	**39.0**	*10*			**15.3**	*10*
	LI	**26.3**	*5*	**60.0**	*5*	**24.2**	*10*		

At Burton Creek, the pitfall trap samples from BU01 and BU02 treatment (mixed sedge species) had slightly higher relative abundance than control and reference samples (Table 5-2).

Live stake treatments exhibited either similar arthropod densities to adjacent controls (e.g., BU01), or lower arthropod densities than adjacent controls (e.g., ES and LI).

Arthropod relative abundance varied greatly between our two pre-Wildlife Physical Works treatment locations at Burton (BUN and BUS), which suggests that small scale, within site differences (e.g., differences in microsite conditions) may account for large differences in local arthropod densities. The Burton WPW pitfall traps installed in the north of the pre-treatment area (BUN) had two-fold greater abundance than those installed in the southern part of the WPW area. Both of the pre-treatment Wildlife Physical Works (WPW) Malaise traps had greater mean abundance than any other samples collected at that site (T, C, and R).

5.3.2 Richness

In total, we collected 49 spider species of 1125 individuals in pitfall traps during the 2017 monitoring season.

We failed to detect a difference in standardized richness of spider species (based on 95% bootstrapped confidence intervals) between revegetation treatment areas and controls at all study sites examined in 2017 (Figure 5-5, Figure 5-6, Figure 5-7).

Spider richness varied by study site and habitat type in 2017, as in previous years. Both Edgewood South and Lower Inonoaklin had relatively successful black cottonwood stake success (1300 to 2533 sph). While richness did not differ between revegetation treatments and controls, at Edgewood South there was a trend towards greater standardized richness at the revegetated habitat (Figure 5-7) which was not found at Lower Inonoaklin, which had low spider abundance (Figure 5-6).

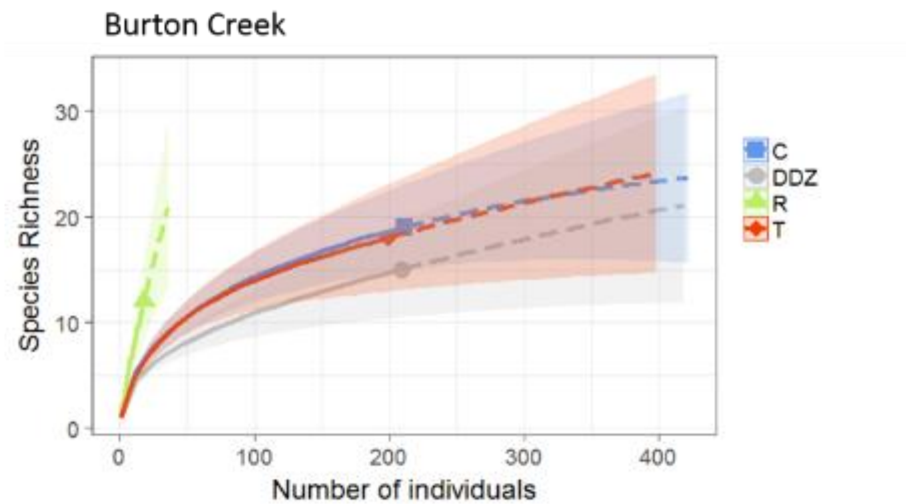

Figure 5-5: Spider species richness for each habitat type sampled at Burton Creek in 2017. Richness is standardized per individual collected. Shaded regions indicate the confidence interval around each richness curve. Points are given at the observed species richness value for each habitat type, followed by extrapolated species richness (dashed line). Solid line = interpolated species richness. Habitat types: T= treatment, C= control, DDZ= pre-treatment Wildlife Physical Works, R= upland reference

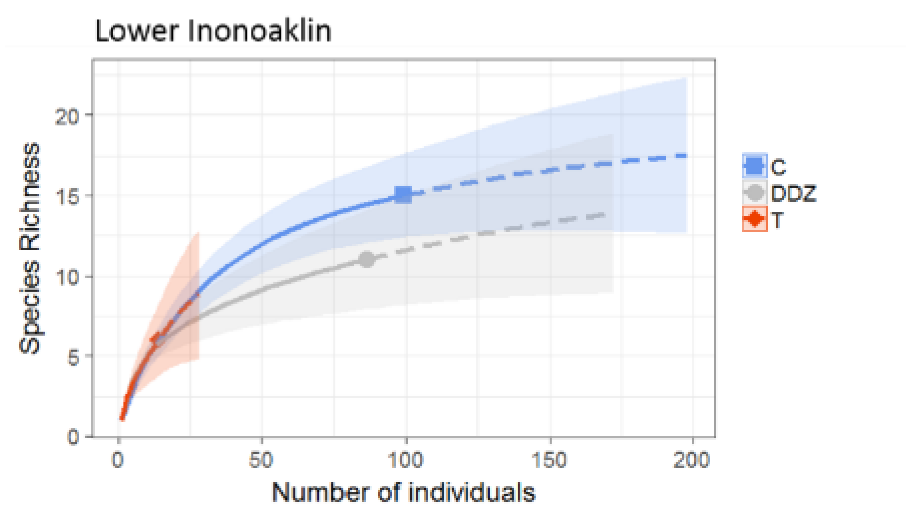

Figure 5-6: Spider species richness for each habitat type sampled at Lower Inonoaklin in 2017. Richness is standardized per individual collected. Shaded regions indicate the confidence interval around each richness curve. Points are given at the observed species richness value for each habitat type, followed by extrapolated species richness (dashed line). Solid line = interpolated species richness. Habitat types: T= treatment, C= control, DDZ= drawdown zone, R= upland reference

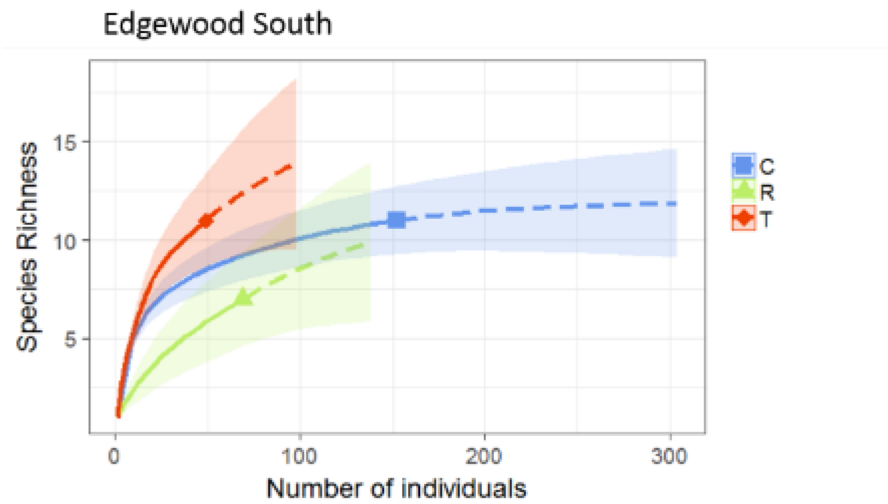

Figure 5-7: Spider species richness for each habitat type sampled at Edgewood South in 2017. Richness is standardized per individual collected. Shaded regions indicate the confidence interval around each richness curve. Points are given at the observed species richness value for each habitat type, followed by extrapolated species richness (dashed line). Solid line = interpolated species richness. Habitat types: T= treatment, C= control, DDZ= drawdown zone, R= upland reference

Five species of Orthoptera were documented in 2017, from 111 individuals, compared to 9 species in 2016. The Camel Cricket, *Pristoceuthophilus celatus*, was found exclusively in the upland reference sites. The remaining four species were observed in open habitats, with no specific preference evident for revegetation treatment or control areas.

5.3.3 Biomass

Patterns in arthropod biomass across treatments were variable, depending on site and trapping method in 2017. Acknowledging low sample sizes for Malaise traps (n = 1 or 2, depending on the site), aerial arthropod biomass tended to be greater in treatments than controls at all sites, except Lower Inonoaklin (Figure 5-8).

For pitfall traps (n = 5 or 10, depending on the site), only one treatment area had greater biomass than the paired control polygon. The BU02 graminoid seedling treatment at Burton Creek (polygon 64) had greater arthropod biomass than the respective control (Figure 5-8). In other sites, where treatments were defined as live stake plantings, control plots either had similar ground-dwelling arthropod biomass (BU01 polygon 25 at Burton Creek and Lower Inonoaklin), or greater biomass than the paired treatment polygons (Edgewood South).

When combining data from arthropod biomass samples over three years of sampling (2015, 2016, and 2017), few patterns emerge across study sites and habitat types (Figure 5-9). Biomass was comparable between control and treatment habitats across all sites, when these three years of data were examined. Thus patterns observed for 2017 should not be independently interpreted without consideration of long-term data that have been collected.

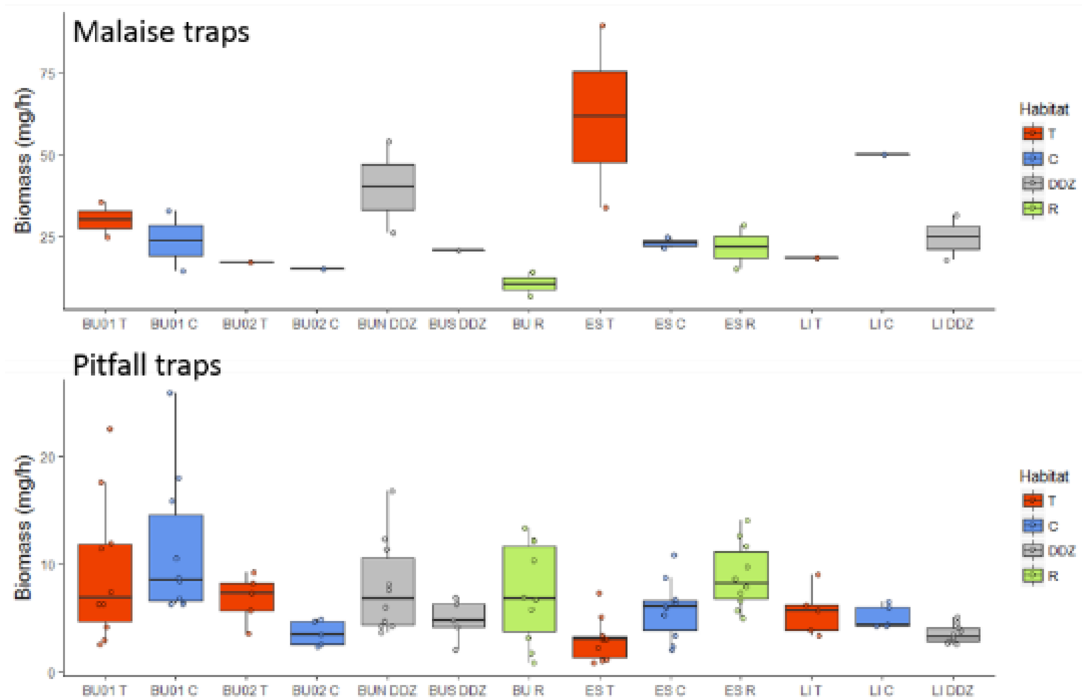

Figure 5-8: Biomass (mg/h) of Malaise (top) and pitfall (bottom) arthropod samples for sites and habitats sampled in the Arrow Lakes Reservoir in 2017. Dot plots are overlaid on boxplots to aid interpretation of sample size and variance (n ≤ 2 for Malaise traps, n ≥ 5 for pitfall traps). BU: Burton Creek (BU01: shrub stakes; BU02: mixed graminoids); LI: Lower Inonoaklin; ES: Edgewood South. T: treatment; C: control; DDZ: drawdown zone; R: reference

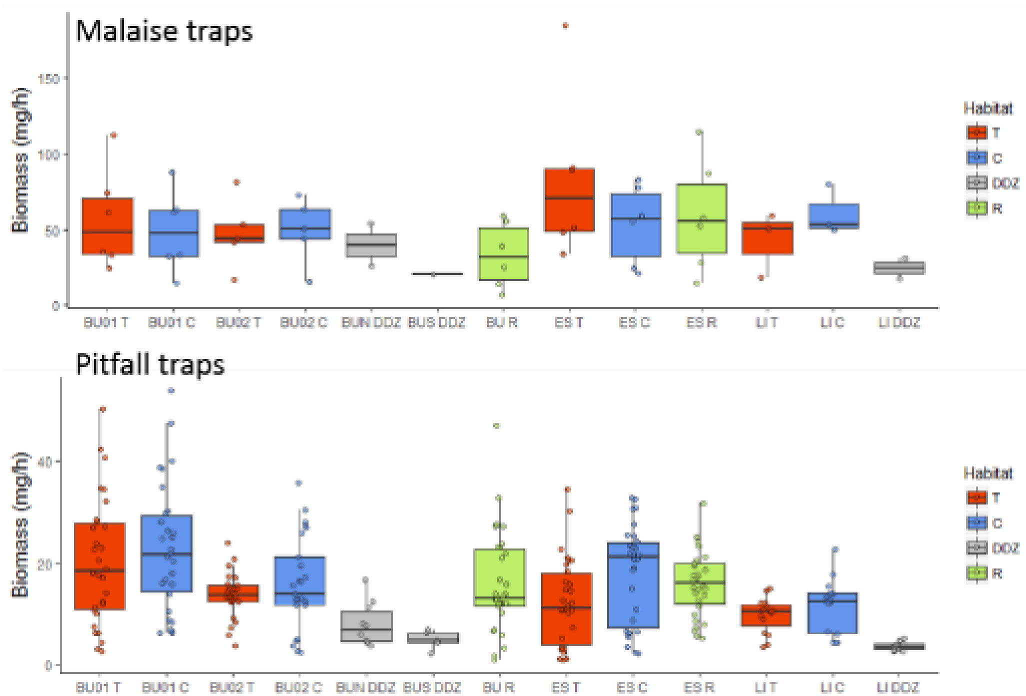

Figure 5-9: Biomass (mg/h) of Malaise (top) and pitfall (bottom) arthropod samples for sites and habitats sampled in the Arrow Lakes Reservoir in years 2015 to 2017. Dot plots are overlaid on boxplots to aid interpretation of sample size and variance. BU: Burton Creek (BU01: shrub stakes; BU02: mixed graminoids); LI: Lower Inonoaklin; ES: Edgewood South. T: Treatment; C: Control; DDZ: drawdown zone; R: reference

5.3.4 Composition

Arthropod composition was similar between revegetation treatment and control samples for Malaise and pitfall trap samples in 2017. Thus, samples had a large portion of shared taxa relative to unique taxa in each habitat type (Figure 5-10). Assemblages were more dissimilar for pitfall traps than Malaise traps between revegetation treatment and controls (as shown by the lesser proportion of shared species in the overlapping ellipses of each Venn Diagram).

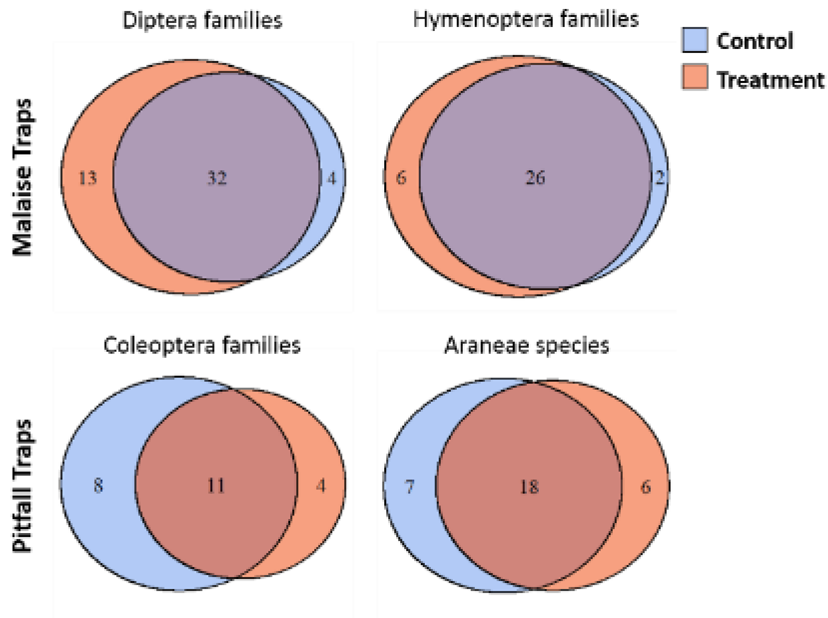

Figure 5-10: Venn diagrams of composition for target arthropod taxa by trapping method and habitat type in 2017. Number of families (or species) unique to each habitat type is given for control and revegetation treatment plots, with the number of shared families (or species) provided in the overlapping regions. Extent of overlap is proportional to the compositional similarity between habitats. All sites are combined.

The redundancy analysis model revealed a significant relationship between spider species assemblages and explanatory variables (i.e., site and vegetation data; RDA: df = 6, F= 1.94, p= 0.001). Sixty-five per cent of the variation in spider species assemblages was explained by the RDA model. The first two axes explained 23 and 14 per cent of the variation, respectively, with assemblages clearly separating by site (Figure 5-11). Site-specific effects included:

- At Lower Inonoaklin treated habitat was associated with one unique spider species (*Walckenaeria vigilax*), as well as higher soil moisture and herb cover.
- Edgewood south treatment was characterised by three spider species (*Neoantistea magna, Phidippus clarus, Castianeira walsinghami*), higher percent cover of live stakes, mineral soil, and rocky substrate.
- The two treatments at Burton Creek (BU01 and BU02) were very similar in terms of species composition (points plotted close together in ordination space). *Gnaphosa parvula* and *Xysticus ferox* were associated with these treatments, both open-habitat ground running spiders that do not require vegetation for prey capture. These sites were characterised by higher per cent cover of organic matter and transplanted graminoid density (as BU02 was a graminoid seedling treatment). These locations also tended to be more sloped than other location sampled.

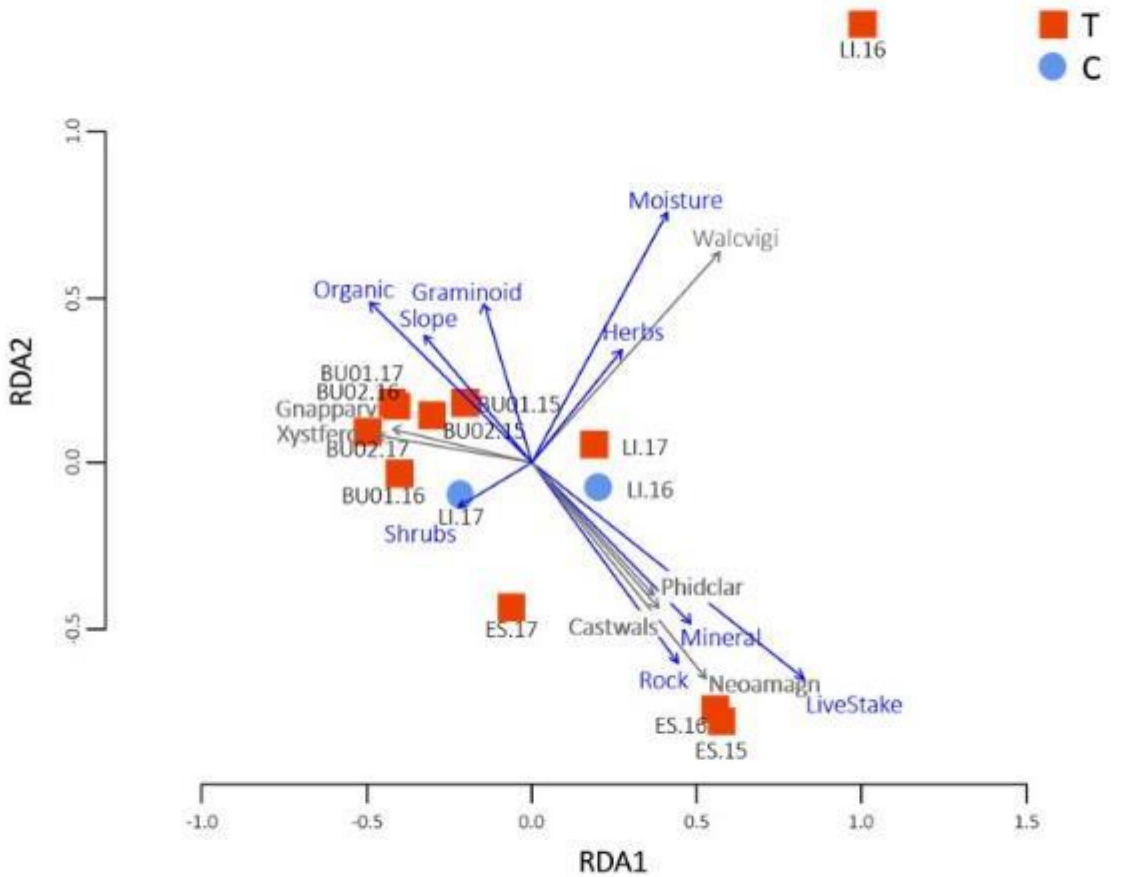

Figure 5-11: Redundancy Analysis (RDA) ordination of Araneae species assemblages collected in pitfall traps, showing relationships among treatments, sites, and explanatory variables. Abundance was standardized by trap effort and distances were computed with the Hellinger distance measure. Environmental vectors (blue arrows) and species vectors (grey) are overlaid for interpretation of relationship with assemblages (length proportional to strength of relationship). Labels are staggered slightly if plotted in the same location. Site codes: BU= Burton, ES= Edgewood South, LI= Lower Inonoaklin; Year codes: 15= 2015, 16= 2016, 17= 2017

5.4 Birds

5.4.1 Reference Condition: Species richness and diversity

There were a few notable trends in richness and diversity (Shannon's H') across years at reference habitats. These values were consistently low in 2011, high in 2017 (Figure 5-12, Figure 5-13); and higher in the 2013-2017 period than in the 2009-2011 years. The broad overlap in the boxplots indicates that richness and diversity values did not significantly differ among most years, though this varied by site (Figure 5-12, Figure 5-13). For example, the richness and diversity trends appeared relatively stable at Burton Creek compared to Edgewood North (Figure 5-12, Figure 5-13).

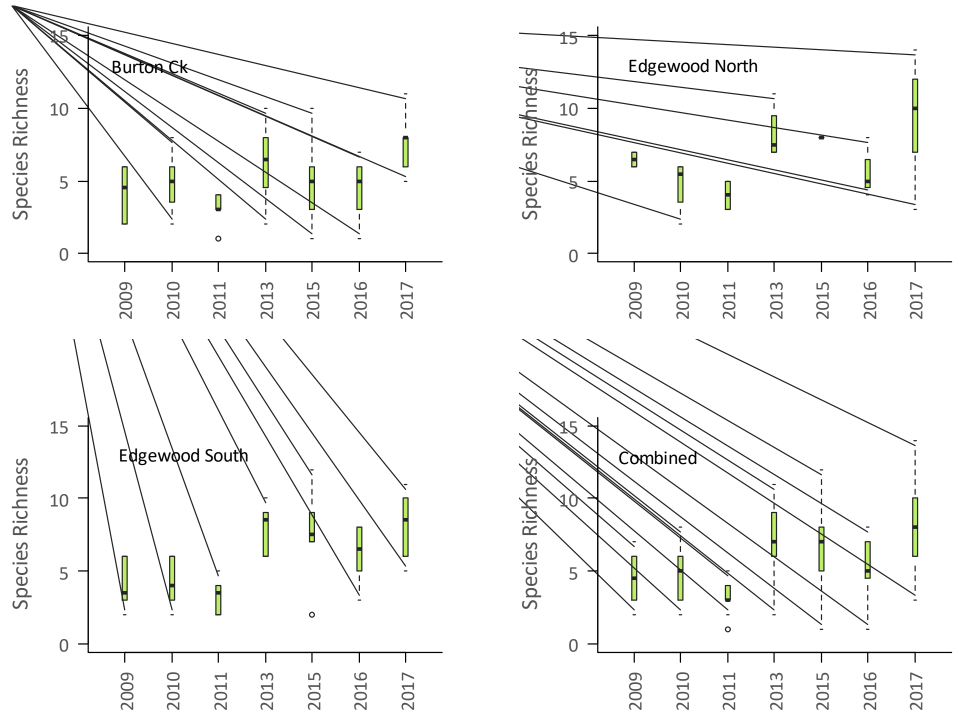

Figure 5-12: Boxplots showing bird species richness at three individual Reference sites above the drawdown zone (labelled), and by those sites pooled (bottom right), from 2009-2017. Note that no surveying was conducted in 2012 and 2014.

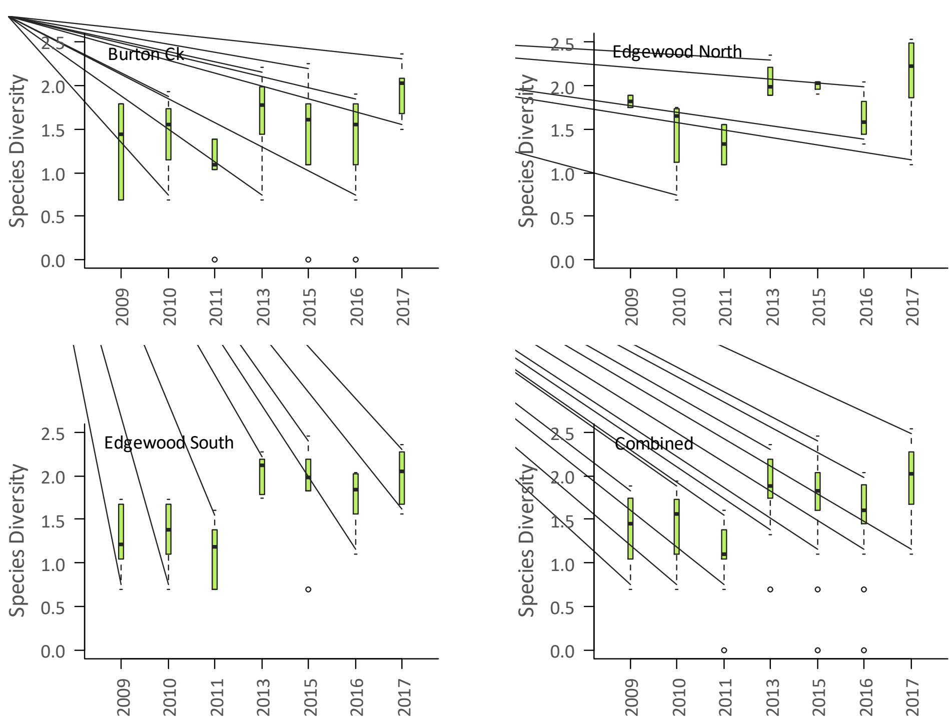

Figure 5-13: Boxplots showing bird species diversity at three individual Reference sites above the drawdown zone (labelled), and by those sites pooled (bottom right), from 2009-2017. Note that no surveying was conducted in 2012 and 2014.

A total of three species of provincial conservation concern have been detected during reference point counts. These are Barn Swallow, Black Swift, and Olive-sided Flycatcher (all blue-listed provincially). The Black Swift is listed by COSEWIC as Endangered, while the swallow and flycatcher are listed as Threatened and Special Concern by COSEWIC respectively. In addition, Common Nighthawk and Evening Grosbeak (both listed as Special Concern) have been documented during reference point counts.

5.4.2 Reservoir Inundation Zone: Species richness and diversity

When richness was compared for these count station types with data from the sites pooled, there were no distinct differences (Figure 5-14). There were some site-specific patterns:

- Within Burton Creek, richness did not differ between treatment and control, excepting in 2015 and 2016 when treatment sites had greater species richness (Figure 5-14). This difference may have been spurious, as the additional species detected in treatment in 2015 (e.g., Black-capped Chickadee, Cedar Waxwing) were not the same as the species in 2016 (e.g., Alder Flycatcher, Lazuli Bunting). Few drawdown zone stations were sampled at Burton, with additional sites being added in 2017 in conjunction with proposed physical works.
- At Edgewood South, control stations consistently have shown higher species richness than treatment stations. However, that greater species richness does not seem due to specific birds. For example, single detections of Song Sparrow have been detected in control sites in two years, while Willow Flycatcher has been detected twice in each of two years (out of seven sampling years). The trend is likely due to the greater proximity of control stations to the forest edge. No distinct patterns in species richness exist at Edgewood North (Figure 5-14).

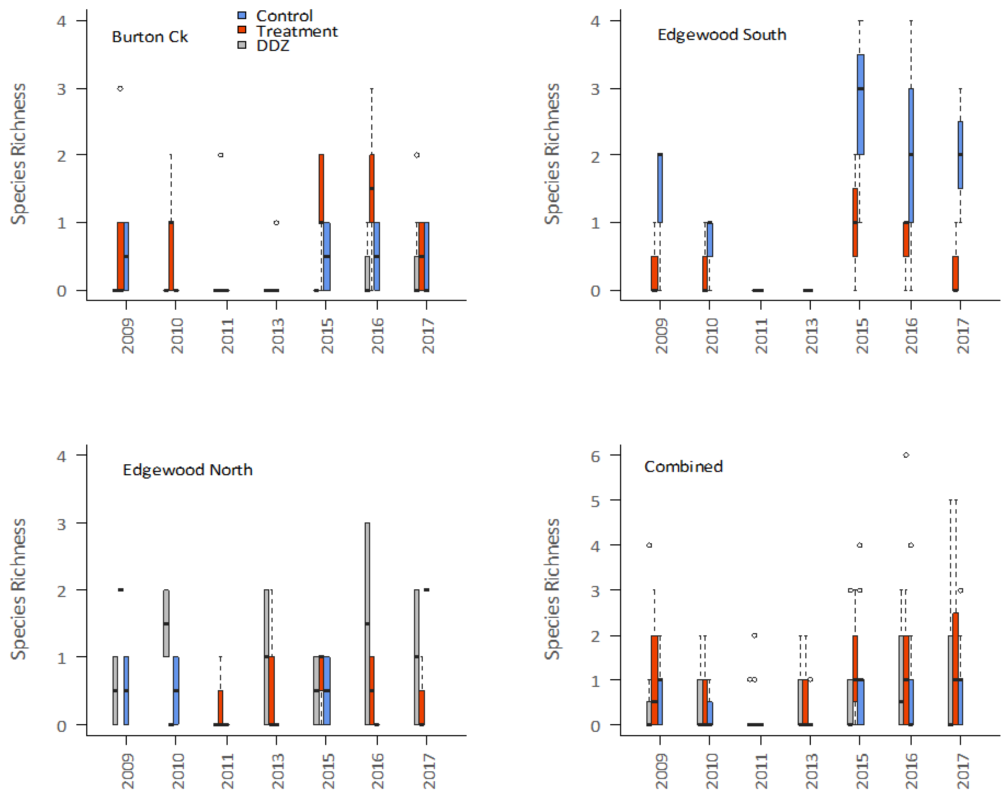

Figure 5-14: Boxplots showing bird species richness by habitat type (treatment [red], control [blue], drawdown zone [grey]) at three individual sites (labelled), and by those sites pooled (bottom right), from 2009-2017. Note that no surveying was conducted in 2012 and 2014.

As diversity accounts for species abundance, diversity values were all very low when comparing points within the reservoir inundation zone. Within the 30 m distance buffer used to assess revegetation effectiveness very few individual birds were detected, resulting in median diversity values being near zero for many stations. General trends are similar to those presented for species richness. Overall (sites pooled), and at Burton Creek (in two years), treatment sites had higher diversity than control sites, though median values were similar for all (Figure 5-15). Edgewood North, in particular, had higher diversity at drawdown zone stations than either control or treatments (Figure 5-15). As per species richness, the control stations at Edgewood South were more diverse than treatment stations.

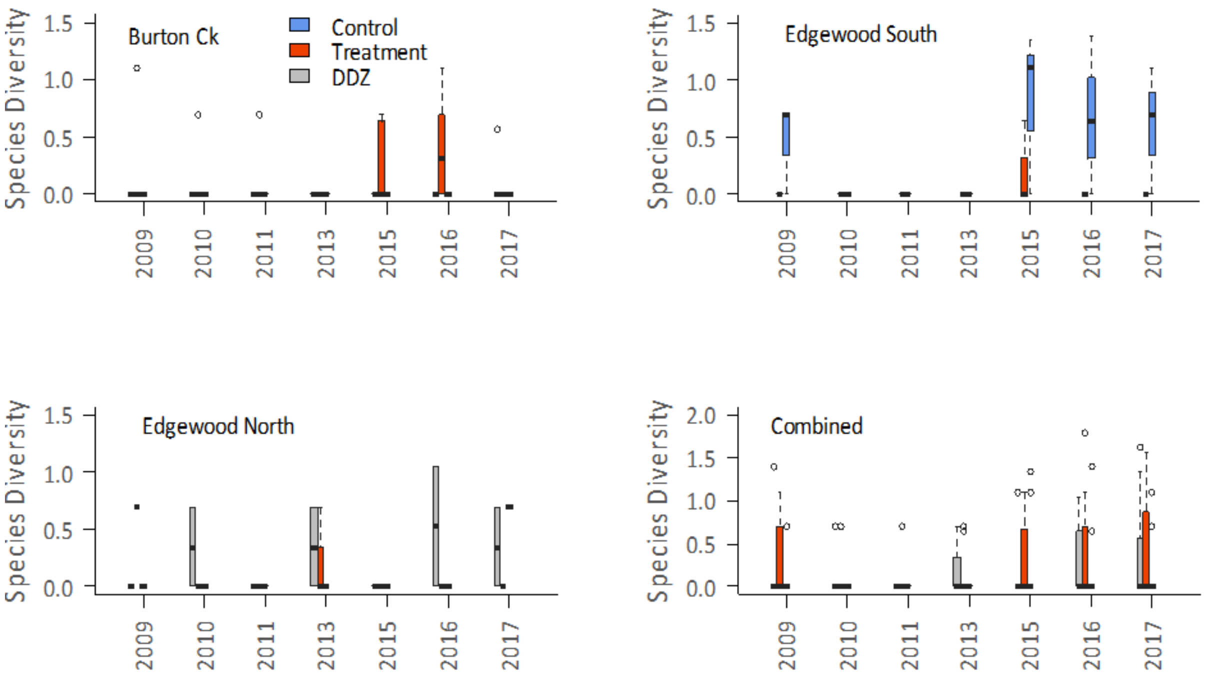

Figure 5-15: Boxplots showing bird species diversity (Shannon's H) by station type (treatment [red], control [blue], drawdown zone [grey]) at three individual sites (labelled), and by those sites pooled (bottom right), from 2009-2017. Note that no surveying was conducted in 2012 and 2014.

5.4.3 Songbird species composition and similarity

The comparison of songbird communities using NMDS with two coefficients (D14 and D7) showed similar structuring under both coefficients (Figure 5-16). In both cases the treatment, control, and drawdown zone stations showed non-assortative clustering, indicating similar songbird communities. Control and treatment points within a particular site often clustered closer together than to the same sample type (e.g., treatment) of a separate site, though not in every case. The Revelstoke Reach sites (8 Mile [8M], Drimmie Creek [DR], and McKay Creek [MK]) are based on only one year of data, and are treated here preliminarily. A PERMANOVA indicated no effect of treatment type on species assemblage (Table 5-3).

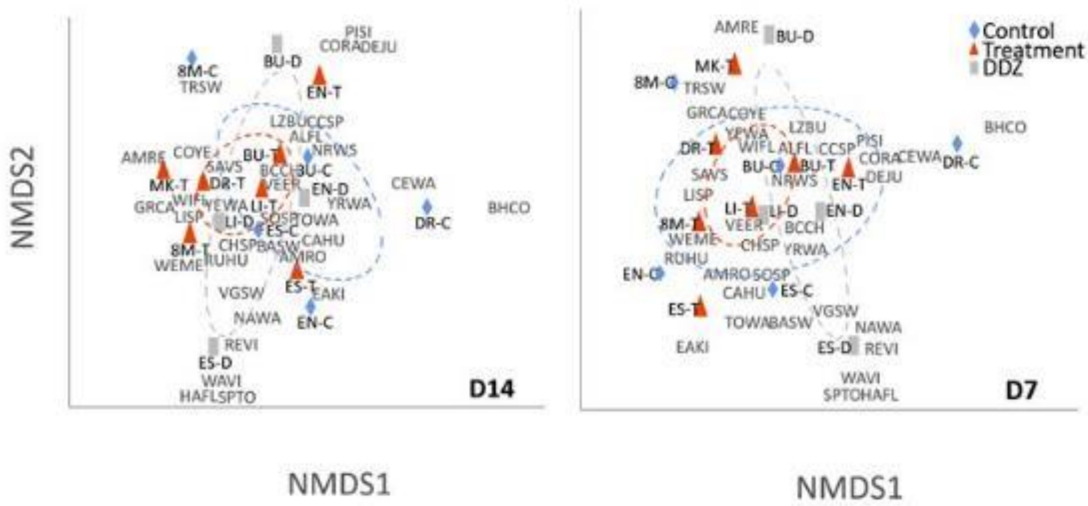

Figure 5-16: Non-metric multidimensional scaling (NMDS) plots showing the similarity among songbird point counts by treatment type based on their species composition. The left panel shows plots based on the D14 (Bray-Curtis) coefficient, the right panel based on the D7 (Sorenson) coefficient. Ordinations are plotted with their 90% confidence ellipses.

Table 5-3. Results of Permutational Multivariate Analysis of Variance (PERMANOVA) tests for statistical differences in species assemblages (D14 resemblance coefficient) among treatment types, blocked by site.

		df	Sums of Squares	Mean Squares	F Model	R^2	p-value
D14	Treatment Type	2	0.650	0.325	0.887	0.120	0.629
	Residuals	13	4.764	0.366		0.880	
	Total	15	5.414			1.000	

A total of twelve species of conservation concern have been detected during point counts in drawdown zone. These include eight species of provincial conservation concern (blue-listed): Barn Swallow, Black Swift, California Gull, Caspian Tern, Double-crested Cormorant, Great Blue Heron, Long-billed Curlew, and Olive-sided Flycatcher. In addition to the provincial listings, Evening Grosbeak, Horned Grebe, Long-billed Curlew and Western Grebe are listed as Special Concern by COSEWIC and/or are listed under Schedule 1 of the Species at Risk Act. Barn Swallow, Bank Swallow, and Olive-sided Flycatcher are federally listed as Threatened, and one species, the Black Swift, is listed as Endangered.

5.4.4 Nesting Evidence

In total, breeding evidence was found for 14 species from Burton Creek, Drimmie Creek, Edgewood North, Edgewood South, Lower Inonoaklin, and McKay Creek in 2016 and 2017 combined (Table 9-1). A total of 52 nests were found (Table 5-4). Most nests were from either shrub-nesters (e.g., Chipping Sparrow, Willow Flycatcher), or ground-nesters (e.g., Spotted Sandpiper) The most frequently encountered was Spotted Sandpiper (19 nests), with breeding evidence detected from all sites except McKay Creek. Shrub and tree-nesting species were found nesting within planted cottonwood stakes on four occasions (American Robin and Cedar Waxwing at Lower Inonoaklin in 2016 and Willow Flycatcher and Chipping Sparrow at Edgewood South in 2017).

The date that nests were found over both years ranged from June 3rd to July 28th. There were 14 documented nest failures and 10 documented nest successes (or probably successes) (Table 5-4). Out of the 14 failures, inundation by rising reservoir levels was implicated in eight. In addition to documented nests, three other recently fledged nestlings were found (Nashville Warbler, Chipping Sparrow, and Savannah Sparrow), indicating successful nesting nearby. The Nashville Warbler was found foraging within the planted cottonwood stakes at Lower Inonoaklin, despite likely nesting somewhere upland, indicating that revegetation, where successful, can provide foraging habitat for fledged birds.

Table 5-4: The nesting fates of the 52 nests located during 2016 and 2017 by study site.

	Nest Fates				
Site	Success	Probable Success	Failure	Unknown	Total
Burton	1	4	1	4	10
Drimmie Creek			3	7	10
Edgewood North	1		1		2
Edgewood South			5	6	11
Lower Inonoaklin		3	3	6	12
McKay Creek		1	1	5	7
Total	2	8	14	28	52

5.5 Bats

From 08 June to 21 September 2017, bat detectors (*n*=14) sampled sites in Lower and Mid-Arrow Lakes for a combined total of 5,719 hours and recorded 281,890 bat calls. When run through Kaleidoscope Pro, 173,991 calls (61.7%) were assigned a species identification.

All 12 bat species that could occur in the study area were classified by Kaleidoscope. Bat species richness ranged from 9 species at Mosquito Creek to a high of 12 species at Edgewood South (Table 5-5). Both Armstrong and Box Lakes each had 10 species, while Burton, Lower Inonoaklin, and West Arrow all had detections of 11 bat species.

Little Brown Myotis (MYOLUC) had 80,356 detections classified by Kaleidoscope making it the most frequently recorded species overall, and it had the most recordings at four sites. Yuma Myotis (MYOYUM) was the next most commonly recorded species with 38,432 assigned detections, and it was the most frequently detected species at two sites. Of the larger bat species, Silver-haired Bat (LASNOC) was the most numerous according to Kaleidoscope, and it was the most frequently documented species at one site. Similar to 2016 results, Fringed Myotis (MYOTHY) and Townsend's Big-eared Bat (CORTOW) were the most infrequently detected species with only 14 and 33 detections, respectively.

Table 5-5: Total number of recordings for each bat species documented from Arrow Lakes Reservoir in 2017. Numbers of recordings are not standardized for sampling effort. "N/A" indicates a species was omitted from analysis for the site based on low probability of occurrence. n= number of detectors given in each site. Species codes are provided in Table 4-2.

Reach	n	CORTOW	EPTFUS	LASCIN	LASNOC	MYOCAL	MYOCIL	MYOEVO	MYOLUC	MYOSEP	MYOTHY	MYOVOL	MYOYUM	Species Richness
Armstrong Lake	1	6	23	397	1290	839	N/A	66	8322	4	0	229	665	**10**
Box Lake	1	3	51	179	354	2454	N/A	20	10521	16	0	404	19862	**10**
Burton Creek	3	2	269	255	1067	1443	N/A	33	9868	3	1	120	948	**11**
Edgewood South	3	2	697	1036	2264	5058	3553	382	19135	12	3	841	4193	**12**
Lower Inonoaklin	3	5	591	1129	4037	4208	N/A	295	10666	27	6	422	12281	**11**
Mosquito Creek	1	0	37	97	497	190	N/A	11	467	5	0	20	99	**9**
West Arrow	2	15	9615	2090	4201	3843	N/A	152	21377	6	4	324	384	**11**

The number of bat recordings per detector-hour (as a measure of relative abundance) was highest at Box Lake, followed by Arrow Wetland (both upland reference locations), while Mosquito Creek had the lowest number of bat recordings per detector-hour (Figure 5-17). Within each site, replicate bat detectors varied in the species relative abundance, which might highlight within site differences in bat activity. One detector at the Burton Creek WPW location (BU3) captured almost four-fold the amount of bat activity (relative abundance) than the other two nearby bat detectors (16.5 recordings/detector-hour vs 4.1 and 4.9 recordings/detector-hour).

One Lower Inonoaklin treatment detector (LI2) recorded much greater bat activity than the other Lower Inonoaklin treatment detector (LI3). Most bat species abundances were comparable between these two detectors, except that the relative abundance of MYOYUM was notably greater in the cottonwood stake treatment at the upper reservoir elevation. This was the second greatest abundance of that species (after Box Lake) across all sites studied.

MYOCIL, which was only included for analyses at Edgewood South, was present in all three Edgewood detector locations, and in greatest relative abundance for the pre-WPW location (adjacent to a small wetland area at the upper elevation of the reservoir).

EPTFUS was only present in minute amounts throughout sampling locations in the drawdown zone sites but was most prominent at the upland reference at Arrow West.

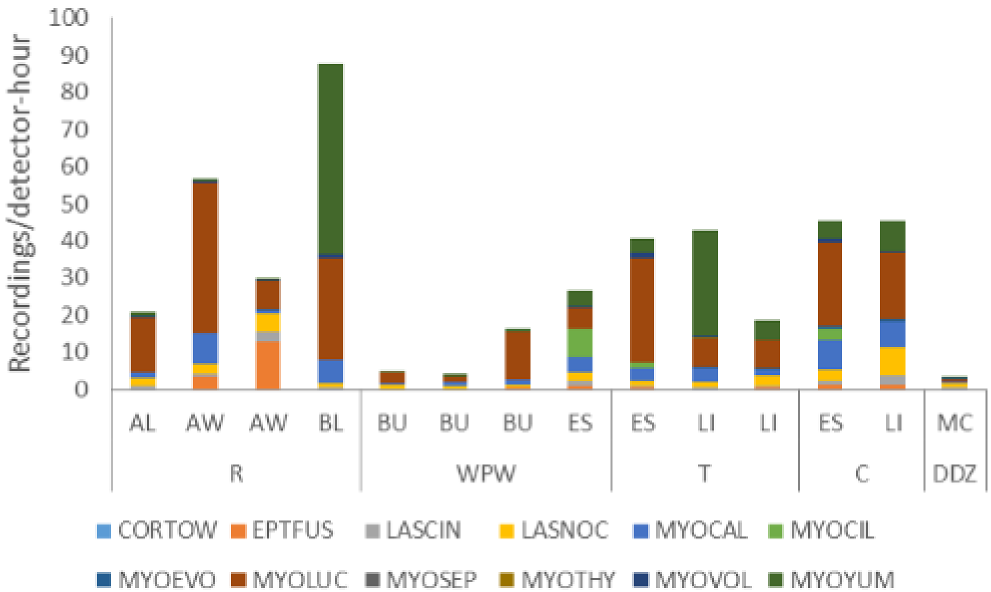

Figure 5-17: Relative abundance (recordings per detector-hour) for all bat species at each site and habitat type sampled in Arrow Lakes Reservoir 2017. Habitat types: R= upland reference, WPW= wildlife physical works, T= revegetation treatment, C= control, DDZ= drawdown zone (unpaired DDZ control)

Data were pooled by site and the proportion of detections for each species was compared (Figure 5-18). Similar to 2016 results, one obvious pattern shown across all sites is the prevalence of *Myotis* species compared to larger bat species (i.e., CORTOW, EPTFUS, LASCIN and LASNOC). Larger bat species combined averaged ~17.4% of the total number of detections, with a range of 1.7 (Box Lake) to 44.3% (Mosquito Creek). Mosquito Creek and West Arrow (37.9%) had exceptionally high representation from larger bat species compared to other sites, while Box Lake's paucity mirrors last year's result (3.7%).

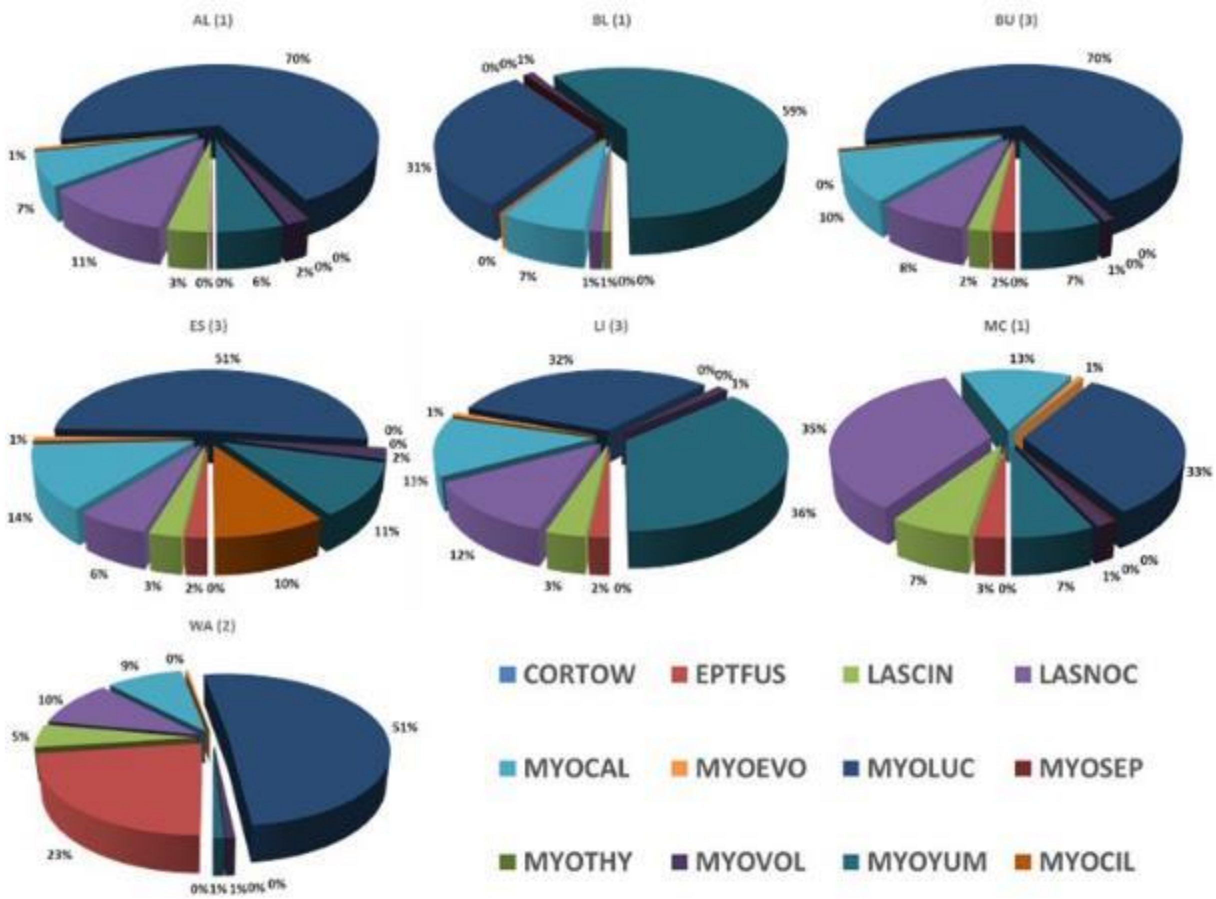

Figure 5-18: Proportion of files assigned to each of the 12 bat species documented from site locations around the Lower and Mid-Arrow Lakes Reservoir, summer 2017. Upland reference sites: AL= Armstrong Lake, BL= Box Lake, WA= West Arrow Wetland; reservoir sites: BU= Burton Wildlife Physical Works, ES= Edgewood South, LI= Lower Inonoaklin. Species codes are provided in Table 4-2. Number of detector units is provided in brackets beside site codes.

Bat species assemblages did not appear to be structured by Site or Habitat Type in 2017 (Figure 5-19). MYOLUC was most associated with the treatment area at Edgewood South, one of the Burton Creek pre-Wildlife Physical Works locations, and two upland reference wetlands (Armstrong Lake and Arrow Wetland). Similarly, higher relative abundance of MYOYUM was found for one treatment bat detector at Lower Inonoaklin (LI2) and the upland reference at Box Lake. Further years of monitoring and compilation of annual data for analyses will provide a more robust assessment of site and habitat-specific patterns in bat species detections, richness, and composition.

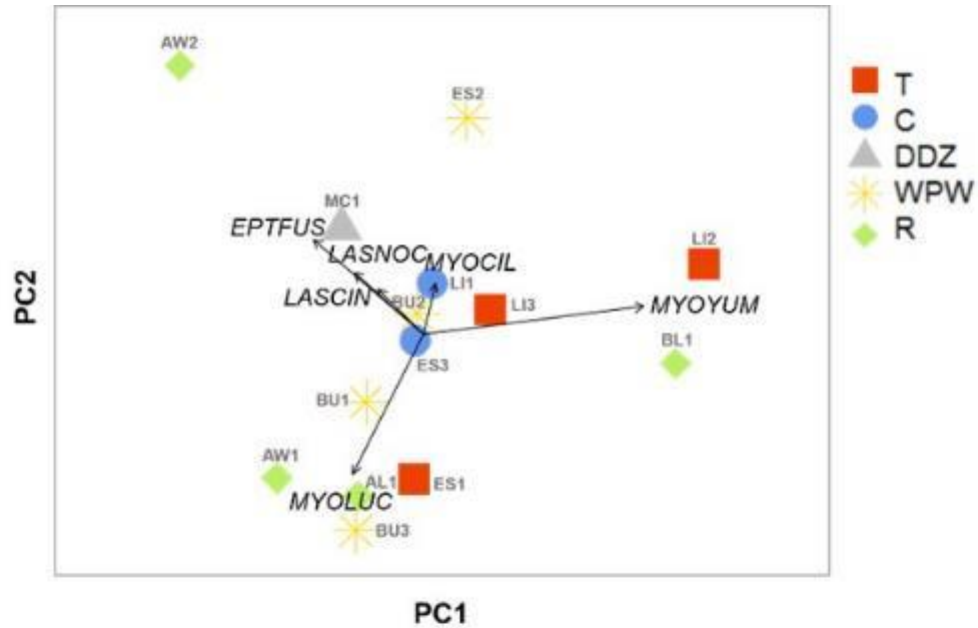

Figure 5-19: Principal Components Analysis (PCA) ordination of Hellinger-transformed relative abundance of 12 Bat species for each bat detector deployed in 2017. Vectors are overlaid for bat species to assess the direction and strength of association with each sampling location (species clustering around the origin removed for clarity). Site codes: BU= Burton, ES= Edgewood South, LI= Lower Inonoaklin, AW= Arrow West, BL= Box Lake, AL= Armstrong Lake, MC= Mosquito Creek

5.6 Wildlife Physical Works

Baseline data collection for certain groups (arthropods, songbirds, and bats) occurred in 2017 and are summarized in this report (see Sections 5.3, 5.4, and 5.5). Other wildlife and vegetation data associated with other BC Hydro-funded programs (e.g., CLBMON-37, CLBMON-33) will be summarized in the next annual report (2018).

Waterfowl data collected in fall 2017 are summarized in Figure 5-20. Creek. In fall 2017 the Burton Creek area was used by up to 40 species of birds with only five species using the physical works location, none of which were waterfowl. In general, waterfowl use of the proposed physical works location is limited to the periods when it is inundated by the reservoir. Adding water to the site results in the use of shallow areas by waterfowl. For example, in 2016 Gadwall (*Anas strepera*), American Wigeon (*Anas americana*), and Mallards (*Anas platyrhynchos)* were observed in the shallow margins of the reservoir. Similar species were observed in 2017, but not in the physical works, mainly as a result of reservoir elevations.

Data collected under CLBMON-37 indicate that two species of gartersnake (*Thamnophis sirtalis and T. elegans*) are abundant at the site. Western Toad (*Anaxyrus boreas*), Columbia Spotted Frog (*Rana luteiventris*) and Pacific Chorus Frog (*Psuedacris regilla)* use habitats in and adjacent to the proposed physical works locations (See results in CLBMON-37 annual reports).

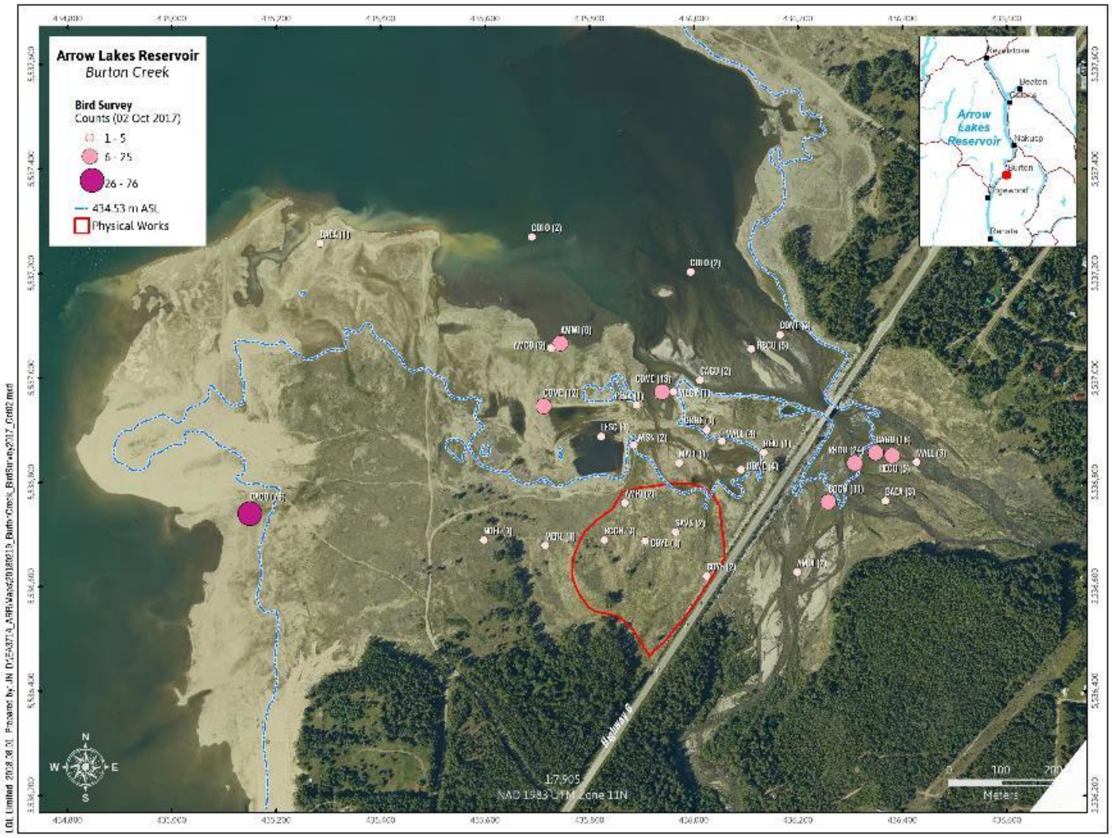

Figure 5-20: Distribution of bird species using the Burton Creek physical works location (red polygon) and surrounding area, October 2, 2017. AMCO = American Coot; AMDI = American Dipper; AMPI = American Pipit; AMWI = American Wigeon; BAEA = Bald Eagle; BCCH = Black-capped Chickadee; BEKI = Belted Kingfisher; BOGU = Bonaparte's Gull; CAGO = Canada Goose; CAGU = California Gull; COLO = Common Loon; COME = Common Merganser; COYE = Common Yellowthroat; GBHE = Great Blue Heron; HEGU = Herring Gull; HOME = Hooded Merganser; = LESC Lesser Scaup; MALL = Mallard; MERL = Merlin; NOFL = Northern Flicker; PESA = Pectoral Sandpiper; RBGU = Ring-billed Gull; SAVS = Savannah Sparrow; WEGR = Western Grebe; WISN = Wilson's Snipe

6.0 DISCUSSION

CLBMON-11B1, initiated in 2009, is a long-term wildlife monitoring project that aims to assess the efficacy of revegetation prescriptions and future wildlife physical works, for enhancing the suitability of habitats in the drawdown zone for wildlife. Based on previous recommendations, the current study focused on arthropod, songbird, and bat communities, all selected for their potentially measurable responses to treatment effects in the drawdown zone of Arrow Lakes Reservoir.

6.1 Revegetation

Results of wildlife effectiveness monitoring to date has failed to detect any clear effect of revegetation prescriptions. There is little indication from annual results that revegetation treatments are effective at enhancing wildlife habitat. If revegetation prescriptions applied in the drawdown zone are effective, they may have a small biological effect size, which is obscured by other effects (e.g., within-site, among site, and among-year differences). These conclusions are preliminary as a comprehensive analysis of data from all years is forthcoming. Additional statistical power gained from analysing a multi-year data set will likely benefit a more thorough evaluation of wildlife responses to revegetation treatments.

Within the drawdown zone control and treatment areas, arthropod composition, biomass, and relative abundance were similar and is consistent with the results of previous annual reports. This suggests that the treatment and control areas sampled are functioning similarly in terms of providing habitat for ground-dwelling and aerial arthropods.

Despite the lack of support for treatment effectiveness to date, it is possible that expanding our spatial replication to sample additional vegetation polygons may reveal treatment success where we have not previously been sampling. If vegetation cover and/or structure are different for treatment areas than adjacent controls, arthropod responses are expected to be detectable. This is due to the high degree of specificity to habitat quality exhibited by terrestrial arthropods. For both ground-dwelling spiders and beetles, vegetation cover increases relative humidity of the soil surface, which provides favourable conditions for many species. Additionally, beetle species (e.g., Carabidae and Staphylinidae) that develop in the upper layers of soil during their larval stages, are highly selective to soil substrate composition, relative humidity, and in some cases salinity and pH of the soil. 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 sedges/grasses may provide a niche for the funnel-web building spiders and for species with lower tolerance to dry sites. Higher vegetation provided by willows/shrubs provides habitat for web-building spiders of various species. Forested habitats provide numerous additional niches not provided by open habitats.

Likewise, songbirds are expected to respond to changes in vegetation structure, for example, through their nesting requirements. Areas containing cottonwood stakes and sedges are likely to provide habitat for bird species that is not available in adjacent drawdown zone areas with bare ground. However, songbird point count data has failed to detect a clear effect of revegetation treatments in comparison with adjacent drawdown zone controls. The number of bird detections is consistently low in treatment and control habitats, while variance is often high. Richness, diversity, and composition patterns provide no consistent trend towards treatment effects. Neither richness nor diversity trends for treatment/control/drawdown zone stations mirror the inter-annual pattern seen in reference plots. This suggests that the (undetermined) drivers behind the inter-annual variation in reference plots are not affecting or resulting in differential responses for bird populations using the habitats of the reservoir drawdown zone.

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 the 2016 and 2017 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 songbird nests in planted cottonwoods is evidence that at least some birds will utilize transplanted vegetation for nesting where suitable characteristics exist. Furthermore, additional species (e.g., Nashville Warbler) may find suitable foraging habitat within the drawdown zone, even when suitable nesting habitat does not exist.

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 is utilizing drawdown zone habitats.

Bat detection data were not found to differ between revegetation treatments and controls monitored in 2017. These included two treatment locations at Lower Inonoaklin and one treatment at Edgewood South. We examined relative abundance, richness, and composition of bats across habitat types and found similar results between treatment and control areas. A large amount of within site (between-detector) variation was also noted, which is not explained by habitat type (e.g., differences between the Burton WPW detectors).

Future years of monitoring will examine species-specific responses in further detail. Despite treatment effects being inconclusive for arthropods, birds, and bats, our sampling has only been conducted in a subset of revegetation prescription polygons available for effectiveness monitoring. To determine if the lack of arthropod response may be due to only these particular sampling areas, we aim to sample additional revegetation treatment polygons in 2018 (see 7.0 RECOMMENDATIONS). By increasing the spatial replication of our sampling to cover a range of vegetation densities, we may better assess the revegetation effectiveness. In successful revegetation areas, focal taxa should provide good indication of the ecological changes provided by wildlife enhancement. These changes should be especially clear in assemblage composition differences between revegetation treatment and controls, based on species-specific habitat requirements.

6.2 Wildlife Physical Works

As stated in Hawkes and Tuttle (2016), wildlife habitat suitability is low for most species groups considered (e.g., arthropods, songbirds and waterfowl). The species richness of bats is as expected (n=11 species), but relative to other areas monitored in and adjacent to Arrow Lakes Reservoir, detection rates are currently low (Table 5-5). The proposed physical works project at Burton Creek is anticipated to improve habitat suitability for wildlife including birds, amphibians, reptiles, mammals (bats), insects (dragonflies) and fish (among others). Species with provincial or federal conservation designation that will benefit from this project include the provincially blue-listed and COSEWIC species of Special Concern, Western Toad (*Anaxyrus boreas*); the provincially blue-listed Townsend's Big-eared Bat (*Corynorhinus townsendii*) and Fringed Myotis (*Myotis thysanodes*); and the COSEWIC endangered Little Brown Myotis (*Myotis lucifugus*) (listed February 27, 2012).

Monitoring at Burton Creek in 2107 (and in previous years when CLBMON-11B1 was implemented) will provide the data necessary to assess the effectives of the proposed physical works to provide habitat for wildlife. The data collected to date will provide a suitable baseline for those future comparisons, and given the proposed timing of the implementation of the physical works, additional baseline data will be collected in 2018.

Following the completion of the design work associated with the physical works at Burton Creek, the performance measures suggested by Hawkes and Tuttle (2016) can be reviewed and revised as needed.

6.3 Management Questions and Hypotheses

Between 2009 and 2017, efforts were made to assess the relationships between revegetation treatments applied in the drawdown zone of Arrow Lakes Wildlife and wildlife use of those treatments. However, as discussed in Hawkes et al. (2018), there were several challenges associated with CLBMON-11B1 that made it difficult to answer the management questions. This reality was mitigated through the revision of the Terms of Reference for the CLBMON-11B projects in June, 2017 (BC Hydro 2017). The 2017 Terms of Reference will guide future work, but our ability to answer the management questions associated with CLBMON-11B1, following work completed in 2017, and based on the 2009 Terms of Reference, is provided below and summarized in Table 6-1. It is necessary to point out that continuing to implement CLBMON-11B1 as per the 2009 Terms of Reference and associated sampling methods, would make it very unlikely that we would be able to answer the current management questions.

At this point, the answer to each question is "inconclusive" for revegetation and "unknown" for wildlife physical works. A summary of the status of each question relative to revegetation and physical works is provided.

6.3.1 MQ-1: Are the revegetation and the wildlife physical works projects effective at enhancing wildlife habitat in the drawdown zone?

Revegetation

Areas containing cottonwood stakes and sedges are likely to provide additional habitat for bird species that is not available in drawdown zone areas with bare ground. Indeed, several species have been observed breeding and foraging within revegetated areas (notably cottonwood stakes). Likewise, arthropod species are highly sensitive to changes in vegetation structure and vegetation density, thus are expected to respond to revegetation areas. On a basic level there is evidence of some enhancement to wildlife habitat, at least for birds, but it is limited. However, a comprehensive analysis of all annual monitoring data collected under CLBMON-11B1 is required for an assessment of revegetation effectiveness. In isolation, annual results failed to detect differences between revegetation prescription treatments and adjacent control areas. Thus, it is not currently possible to fully answer whether revegetation prescriptions are enhancing wildlife habitat in the drawdown zone. Our ability to detect wildlife responses may be hindered by various factors related to the study design of revegetation work: 1) the size of the revegetation treatments and their proximity to adjacent habitat may obscure patterns in wildlife use; 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; and 5) pre-treatment within-site, and among-site variation obscures overall trends in wildlife habitat use.

Physical Works

Development of potential wildlife physical works (WPW) are ongoing. Projects have been identified (Hawkes and Tuttle 2016) and implementation is scheduled for Burton Creek in 2018 or 2019. One season of pre-WPW sampling has been conducted to serve as a baseline for future monitoring. 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. Additional baseline data collection is recommended at the Burton WPW site in 2018.

6.3.2 MQ-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 suggests that revegetation prescriptions are not highly effective at enhancing wildlife habitat in the drawdown zone. The biomass of arthropods is a key response variable 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. The clearest evidence of increased productivity is the observation of a few birds nesting in revegetation treatments, notably in cottonwood plantings. Nesting productivity may thus have increased for a few species or individuals relative to the pre-revegetated state. Future years of monitoring songbird nesting success in and outside of the treatment areas will provide more data with respect to productivity of songbird species in the drawdown zone.

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.

6.3.3 MQ-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.

6.4 Management Questions - Summary

The methods currently used are appropriate for collecting data that can be used to answer specific questions. However, 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 continued pre-treatment sampling at proposed physical works areas (until implementation) 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

<table>
<tr><th rowspan="2">MQ</th><th rowspan="2">Able to Address MQ?</th><th colspan="2">Scope</th><th rowspan="2">Sources of Uncertainty/Limitations</th></tr>
<tr><th>Current supporting results</th><th>Suggested modifications to methods where applicable</th></tr>
<tr><td>1. Are the revegetation and the wildlife physical works projects effective at enhancing wildlife habitat in the drawdown zone?</td><td>Inconclusive</td><td>There is evidence of species-specific responses to revegetated areas for some spider species but results for other taxa are inconclusive. The data do indicate that wildlife are using all habitat types, but current results show little difference between control and treatment plots.

Physical Works: Unknown.</td><td>• Refocus the study to sample across a gradient of revegetation treatment success. Use data from CLBMON-12 (Miller et al. 2018) and CLBMON-35 (Adama et al. 208, draft) to select sites and increase replication. Pair treatment sites with untreated sites to compare metrics of wildlife use.
• Include waterfowl and shorebirds as a focal taxa, particularly at proposed physical works sites.
• Where applicable, utilize data collected under other programs (e.g., CLBMON-11B2 and 36) to augment data collected under CLBMON-11B1).
• Continue to collect Conduct pre-treatment sampling prior to physical works implementation for all taxa (Burton Creek).</td><td>• 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
• Variable reservoir operations
• Physical works have not been implemented</td></tr>
<tr><td>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?</td><td>Inconclusive</td><td>Revegetation treatments: 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.

Physical Works: Unknown.</td><td>• See above</td><td>• See above</td></tr>
</table>

MQ	Able to Address MQ?	Scope		Sources of Uncertainty/Limitations
		Current supporting results	Suggested modifications to methods where applicable	
3. Are some methods or techniques more effective than others at enhancing wildlife habitat in the drawdown zone?	Inconclusive	Revegetation treatments: 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. A review of revegetation treatments is available in Miller et al. (2018) and should be incorporated into assessments of wildlife habitat suitability in the drawdown zone of Arrow Lakes Reservoir. Physical Works: Unknown.	• See above • A review of revegetation treatments is available in Miller et al. (2018) and should be incorporated into assessments of wildlife habitat suitability in the drawdown zone of Arrow Lakes Reservoir	• See above

7.0 RECOMMENDATIONS

In 2017, the Terms of Reference for CLBMON-11B1 were revised (Revision 1, June 29, 2017, BC Hydro 2017). This revision occurred after the implementation of CLBMON-11B1 in 2017. As such, the work conducted in 2017 was based on the previous Terms of Reference (BC Hydro 2009) and 2017 marks the final year of implementation of CLBMON-11B1 based on the 2009 Terms of Reference. All future work on CLBMON-11B1 will be based on the 2017 Terms of Reference, which requires changes to both the focus of the program and the study design. The proposed changes to the methods are not materially different than those used between 2009 and 2017, but the focus of the program is. The recommendations provided below are intended to focus the assessment of specific revegetation prescriptions applied in the drawdown zone of Arrow Lakes Reservoir relative to their use by wildlife. The change in focus and data collection aims to answer specific questions about the effectiveness of certain revegetation treatments to enhance the suitability of the drawdown zone for wildlife.

1. **Expand the scope of sampling to include more successful revegetation treatments not previously sampled under CLBMON-11B1, increase sample size, and improve specificity of treatment monitoring.** Data from CLBMON-12 (Miller et al. 2018) and CLBMON-35 (Adama et al. 2018, draft) provide the data necessary to determine if additional areas could be sampled to increase replication of revegetation treatments. These data provide a summary of the status of the revegetation treatments trialed in the drawdown zone of Arrow Lakes Reservoir. We propose sampling from treated areas representing a gradient of success (e.g., low to high) to test the response of arthropods and birds to varying cover and density of vegetation, using the current sampling methods. Data from treated (revegetated) areas could be compared to untreated areas to test for treatment effects. By sampling across a gradient of success, a regression analysis framework could be adopted to predict whether revegetation affects arthropod biomass, species composition, or provides nesting habitat for birds (for example).

   Between 2009 and 2016, most work completed under CLMBON-11B1 was constrained to the area between Shelter Bay and the Hugh Keenleyside Dam. In 2017, several areas treated in Revelstoke Reach were sampled for songbirds only (Table 3-1). To better assess the efficacy of CLBWORKS-2 revegetation treatments, arthropod and bird sampling should be extended to locations in Revelstoke Reach in addition to our study sites established south of Shelter Bay.

   Based on data presented in Miller et al. (2018) and Adama et al (2018, draft), we also see opportunities for increasing sample size in specific locations treated under CLBWORKS-2. For example, arthropod sampling currently occurs in a single live stake polygon at Edgewood South (polygon 3; 1400 live stakes/ha). However, with only one treatment area within a study site, statistical power is limited due to site-specific variation and sample size. Sample size could be increased by sampling from Edgewood South polygon 1, which is comparable in live stake density to polygon 3 (1267 live stakes/ha). At Lower Inonoaklin, we are currently sampling arthropods in polygons 13 (1033 live stakes/ha and failed graminoid treatment with 0 stems/ha remaining in 2017) and polygon 16 (650 stems/ha of live stakes). These are currently the most successful live stake treatment areas within Lower Inonoaklin, however, more successful live stake treatments are available at 9 Mile and 12 Mile (Drimmie Cr.), at Revelstoke Reach. 9 Mile contains the greatest live stake density of any revegetation treatment, with

2600 to 2840 stems/ha on average within polygons 68 and RR14, respectively. Drimmie Creek has the second greatest live stake densities, with 2000 to 2800 stems/ha on average within polygons 76 and 78, respectively.

In terms of assessing the effectiveness of graminoid seedling revegetation treatments, we are currently sampling within one treatment polygon at Burton (BU02, polygon 64), which has a density of 1650 sedge stems per hectare. An additional treatment polygon at Burton (polygon 20) contains 14,360 stems/ha of Kellogg's sedge plugs and would be a beneficial sampling location to assess the effectiveness of a successful sedge plug treatment. Likewise, arthropod sampling could be replicated within successful sedge plug treatments at Lower Inonoaklin polygons 19 and 17, which contains 12,200 and 10,200 stems/ha, respectively. Outside of these currently sampled sites, there are successful graminoid seedling treatments at East Arrow Park (polygon 43= 15,800 stems/ha, polygon 41= 14,400 stems/ha, and polygon 11= 10,950 stems/ha) and Arrow Park North (polygon 15= 16120 stems/ha, polygon 14= 11600 stems/ha).

2. **Utilize nest search data collected under CLBMON-11B2.** More extensive nest searching is being completed under other CLBMON-11B modules. A review of data collected is needed to better assess the productivity of bird populations within revegetation areas in the drawdown zone and paired controls. Data from CLBMON-11B2 should be utilized in CLBMON-11B1 to assess revegetation efficacy and habitat use by birds in Revelstoke Reach. Nest searching will continue in sample sites south of Shelter Bay.
3. **Compile data from all relevant CLBMON projects.** In addition to the baseline data collected at the Burton Creek physical works location all relevant data from other CLBMON projects (CLBMON-37 and previous iterations of CLBMON-11B1) should be compiled to more fully describe the baseline conditions at the proposed site. This will expand on the summary in Hawkes and Tuttle (2016) and included all data.
4. **Discontinue the use of non-drawdown zone reference sites for arthropods and birds.** Future implementation years should focus on the collection of data from paired treated (revegetated) and control (not revegetated) areas in the drawdown zone to assess the efficacy of revegetation to provide or improve habitat for wildlife.
5. **Consider further vegetation monitoring** for Arrow Lakes Reservoir, to align with sampling locations of CLBMON-11B1. Developing a relational set of data for both wildlife taxa and vegetation at each sampling location would be useful for determining the influence of vegetation cover and structure on taxa under study. Currently, a subset of sampling points align with data collected under CLBMON-12, which is helpful but a full complement of site-specific explanatory data is desirable from an effectiveness monitoring perspective.
6. **Continue to 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 or waterfowl during these periods.

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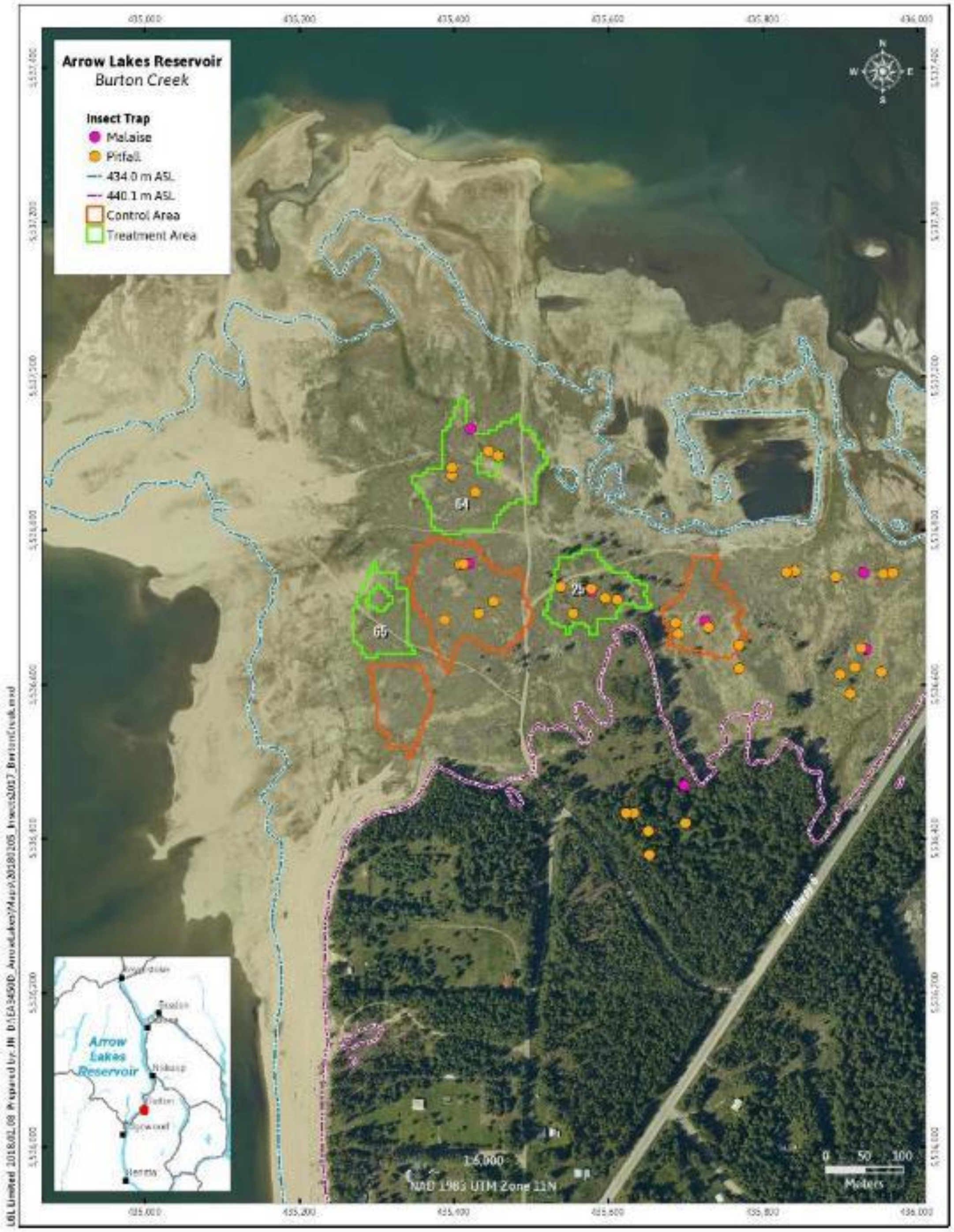
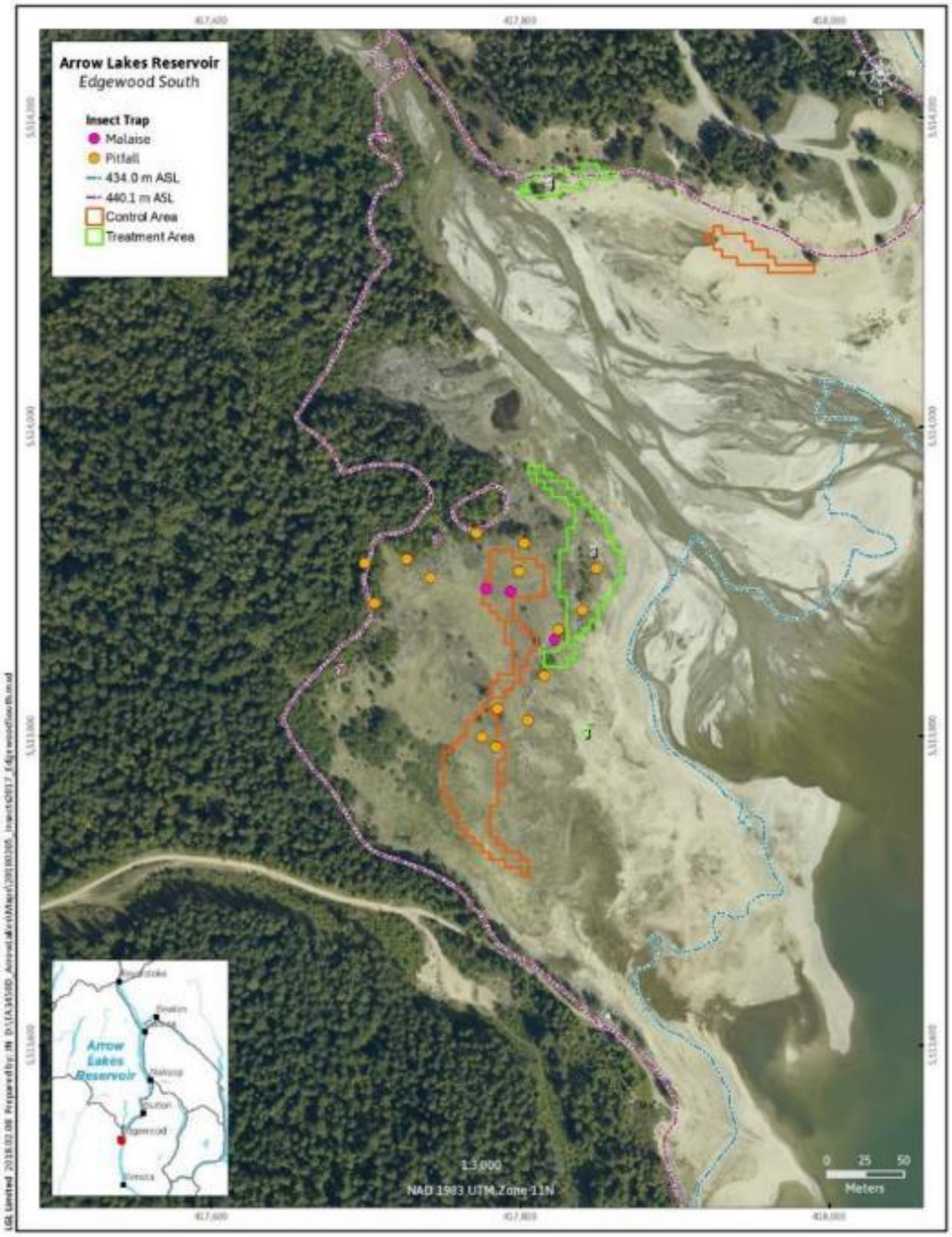
9.0 APPENDICES

Appendix A: Maps of Malaise and pitfall trap locations for 2017



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

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



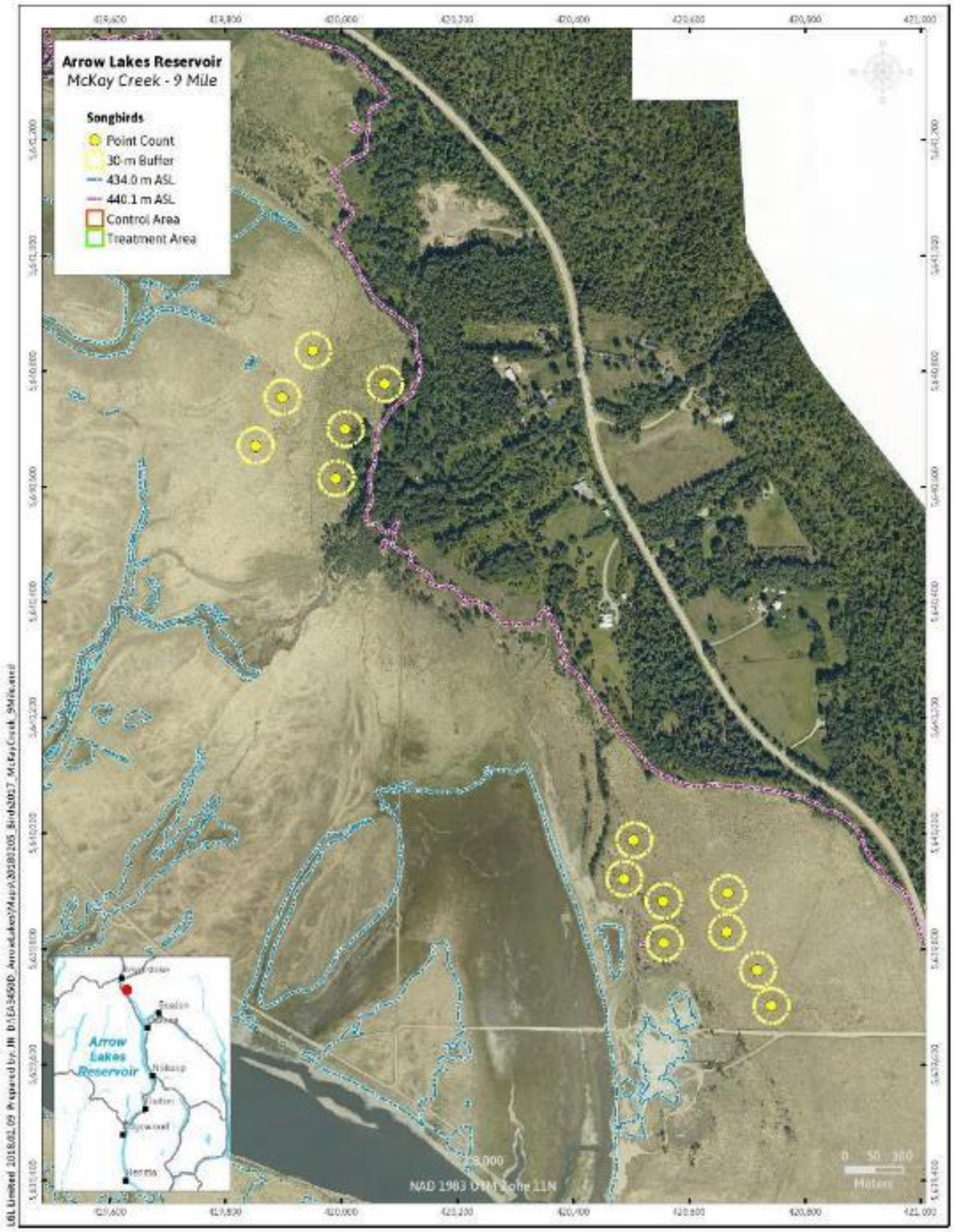
Map 3: **Distribution of Malaise and pitfall traps at Edgewood South**

Appendix B: Number of point count stations by year, site, and habitat type.

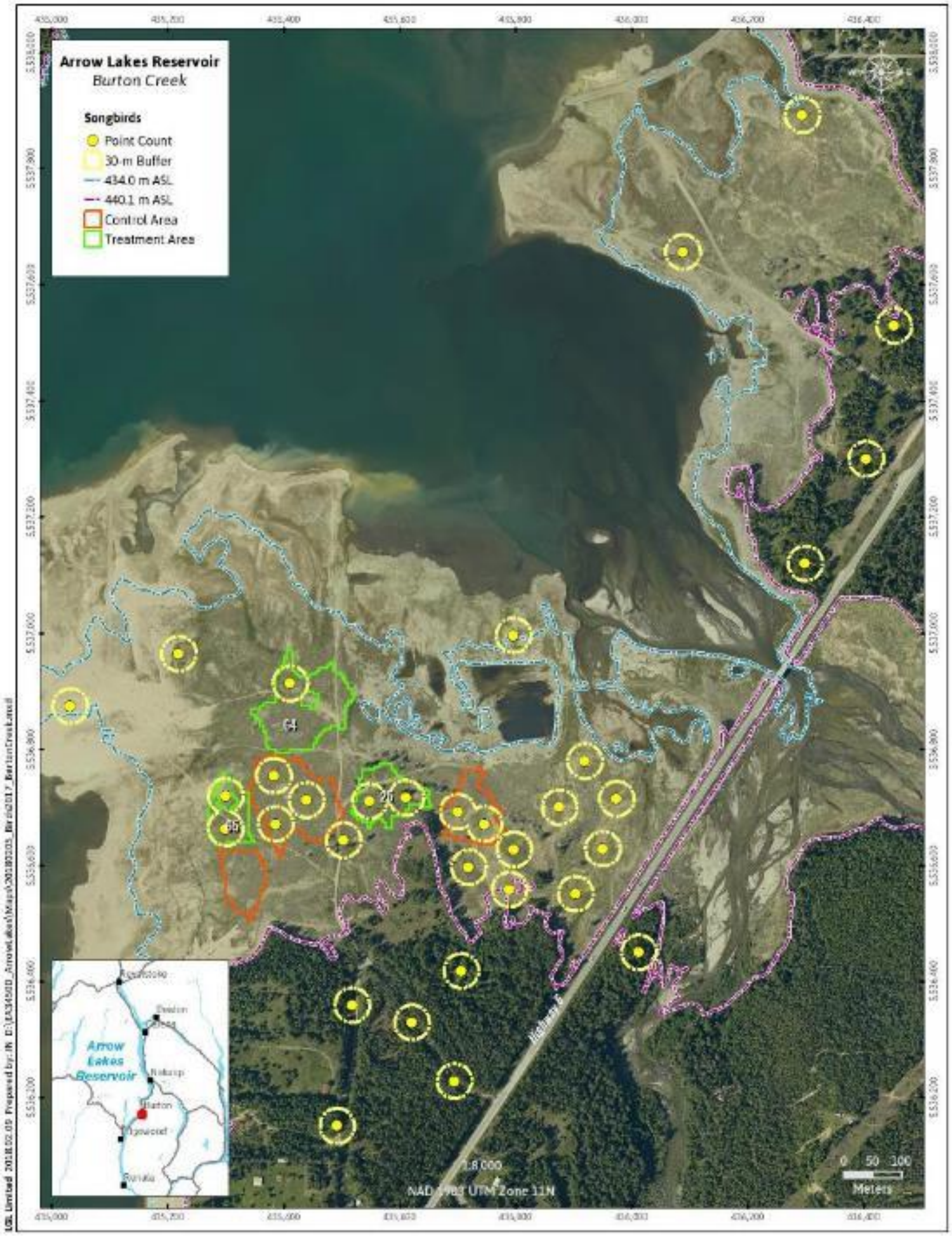
C = Control, T = Treatment, DDZ = Drawdown Zone, R = Reference

Site	Treatment	Year							
		2009	2010	2011	2013	2015	2016	2017	Total
Beaton Arm	DDZ	5	5	5	7	5	4	0	7
	R	9	9	9	9	9	9	0	9
Burton Creek	C	5	7	7	7	6	6	6	7
	T	6	6	6	6	6	6	6	6
	DDZ	5	5	5	5	5	4	12	12
	R	6	9	6	9	9	9	9	9
East Arrow Park	C	9	9	9	9	0	3	0	9
	T	9	9	9	8	0	5	0	9
	DDZ	2	2	2	2	0	2	0	2
	R	11	11	10	13	0	7	0	13
Edgewood North	C	2	2	2	2	2	2	2	2
	T	3	4	4	4	4	4	4	4
	DDZ	2	2	2	2	2	2	2	2
	R	2	6	2	4	4	4	6	6
Edgewood South	C	3	3	3	3	3	3	3	3
	T	3	3	2	3	3	3	3	3
	DDZ	1	0	0	0	1	0	0	1
	R	6	6	6	6	6	6	6	6
Lower Inonoaklin	T	0	0	8	8	7	8	7	8
	DDZ	0	0	1	1	1	1	3	3
Mosquito Creek	DDZ	9	8	9	9	9	9	0	3
	R	9	8	9	9	9	9	0	3
McKay Creek	C	0	0	0	0	0	0	3	9
	T	0	0	0	0	0	0	3	9
12 Mile	C	0	0	0	0	0	0	4	4
	T	0	0	0	0	0	0	4	4
9 Mile	C	0	0	0	0	0	0	4	4
	T	0	0	0	0	0	0	4	4
Total	C	19	21	21	21	11	14	22	38
	T	21	22	29	29	20	26	31	47
	DDZ	24	22	24	26	23	22	17	30
	R	43	49	42	50	37	44	21	46
	Total	*107*	*114*	*116*	*126*	*91*	*106*	*91*	*161*

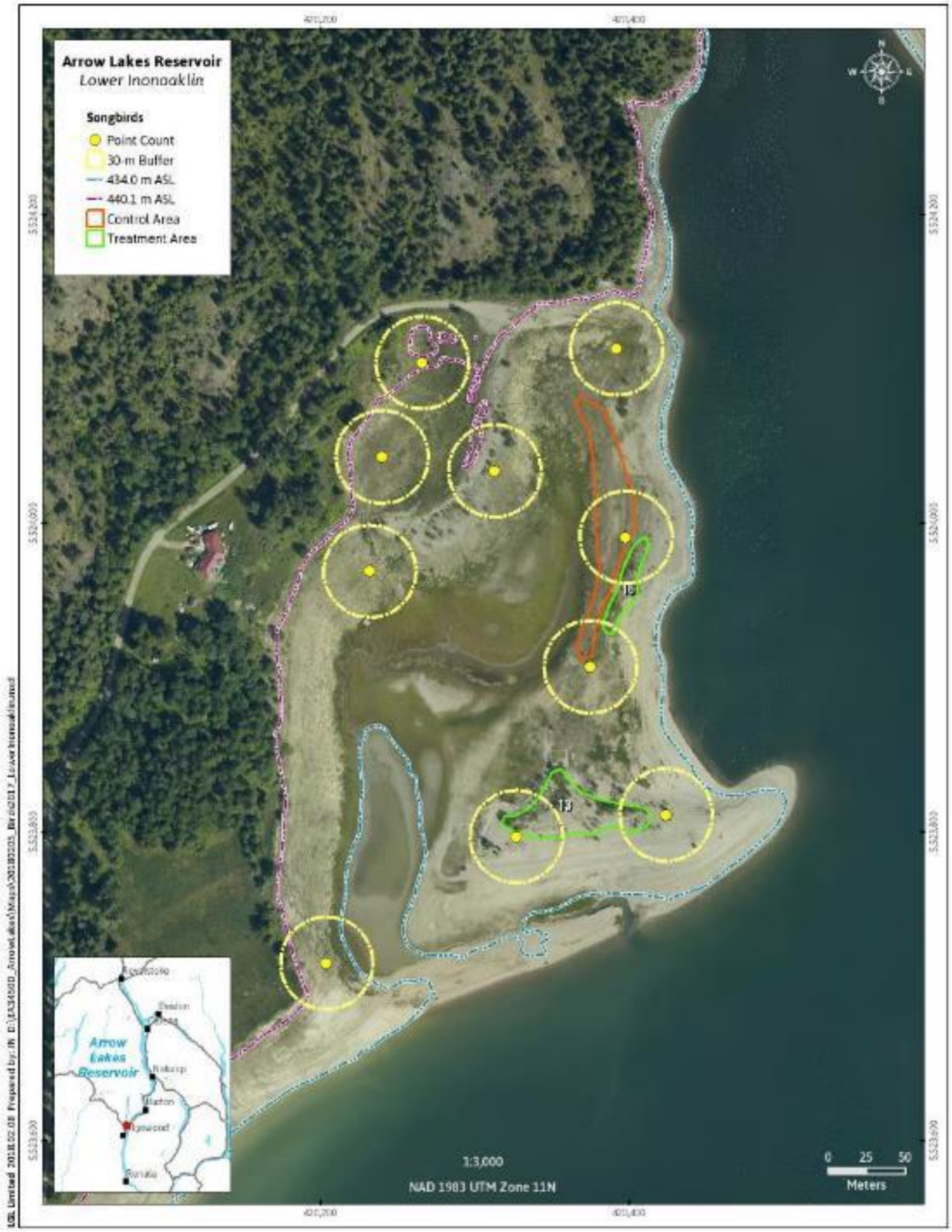
Appendix C: Maps of songbird point count stations for 2017



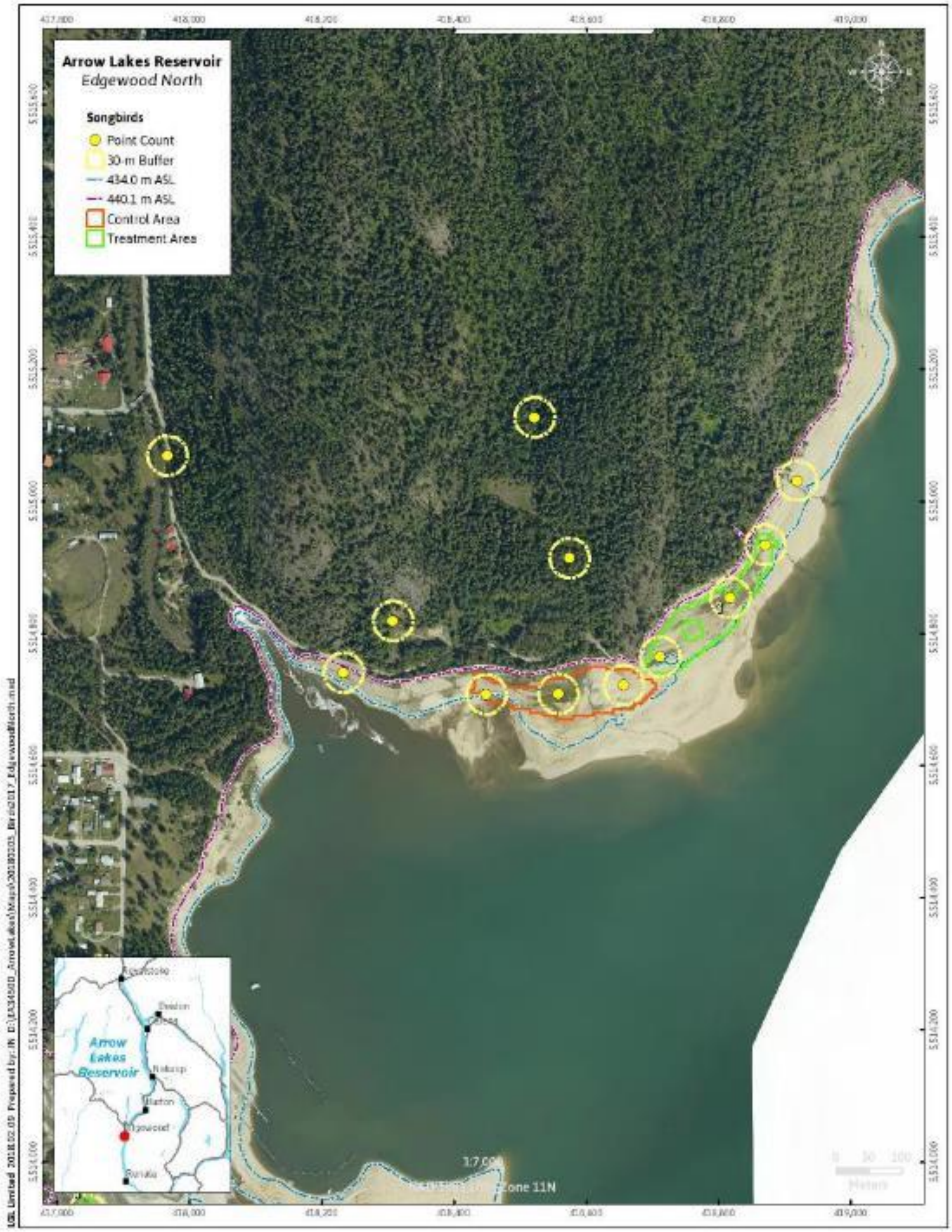
Map 4: Distribution of songbird point count stations at McKay Creek



Map 5: Distribution of songbird point count stations at Burton Creek



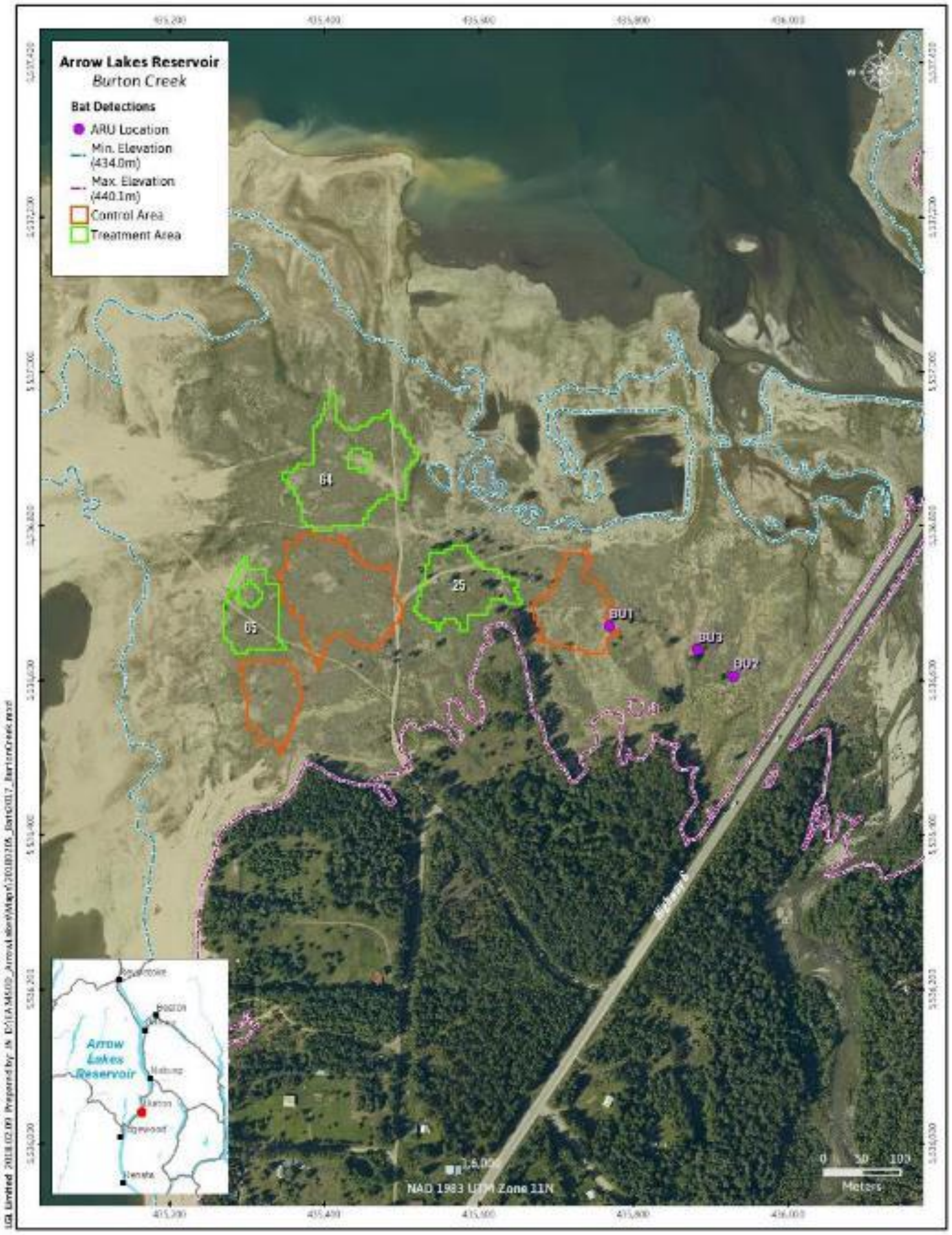
Map 6: **Distribution of songbird point count stations at Lower Inonoaklin**



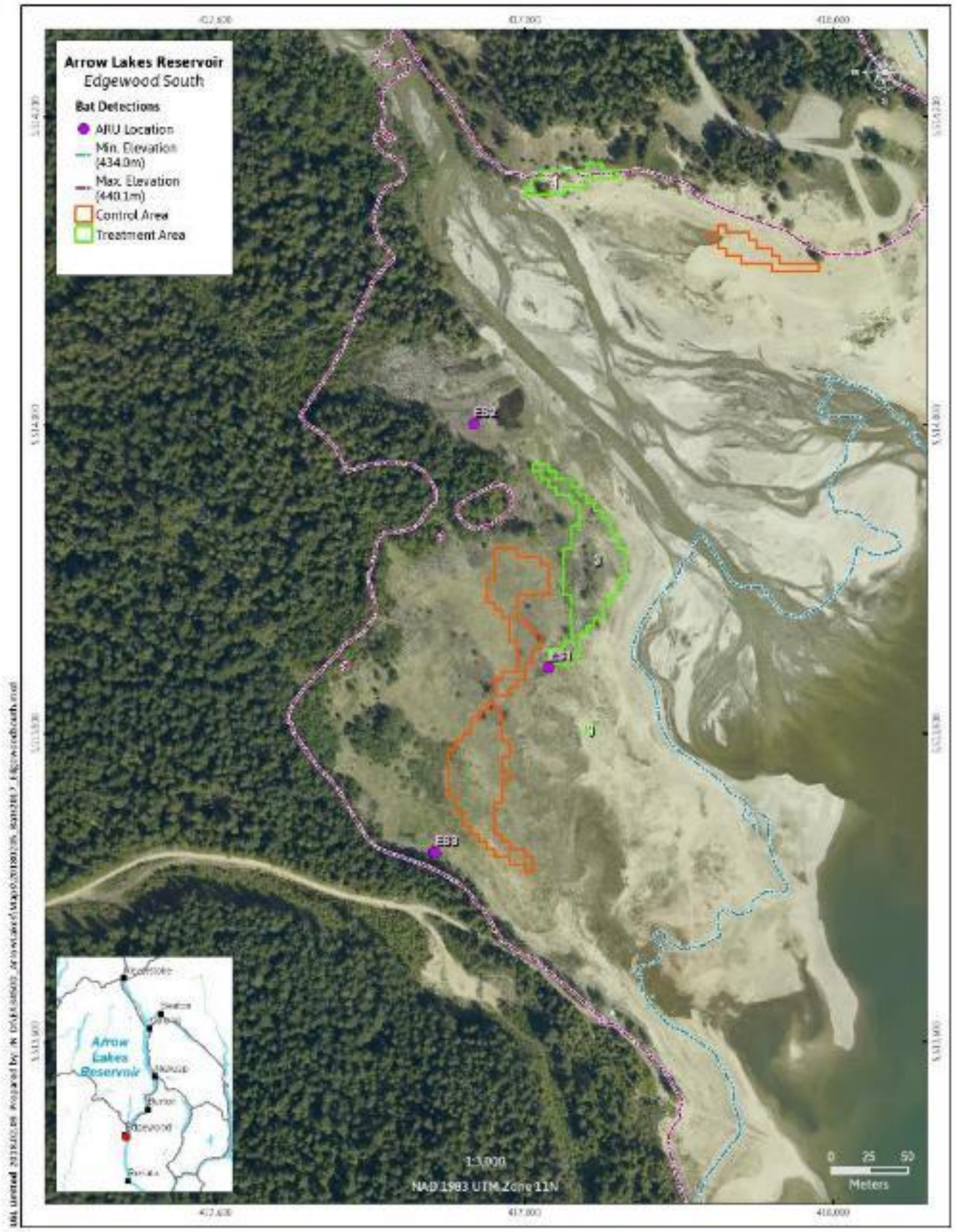
Map 7: **Distribution of songbird point count stations at Edgewood North**

Map 8: **Distribution of songbird point count stations at Edgewood South**

Appendix D: Maps of bat detector (ARU) locations for 2017

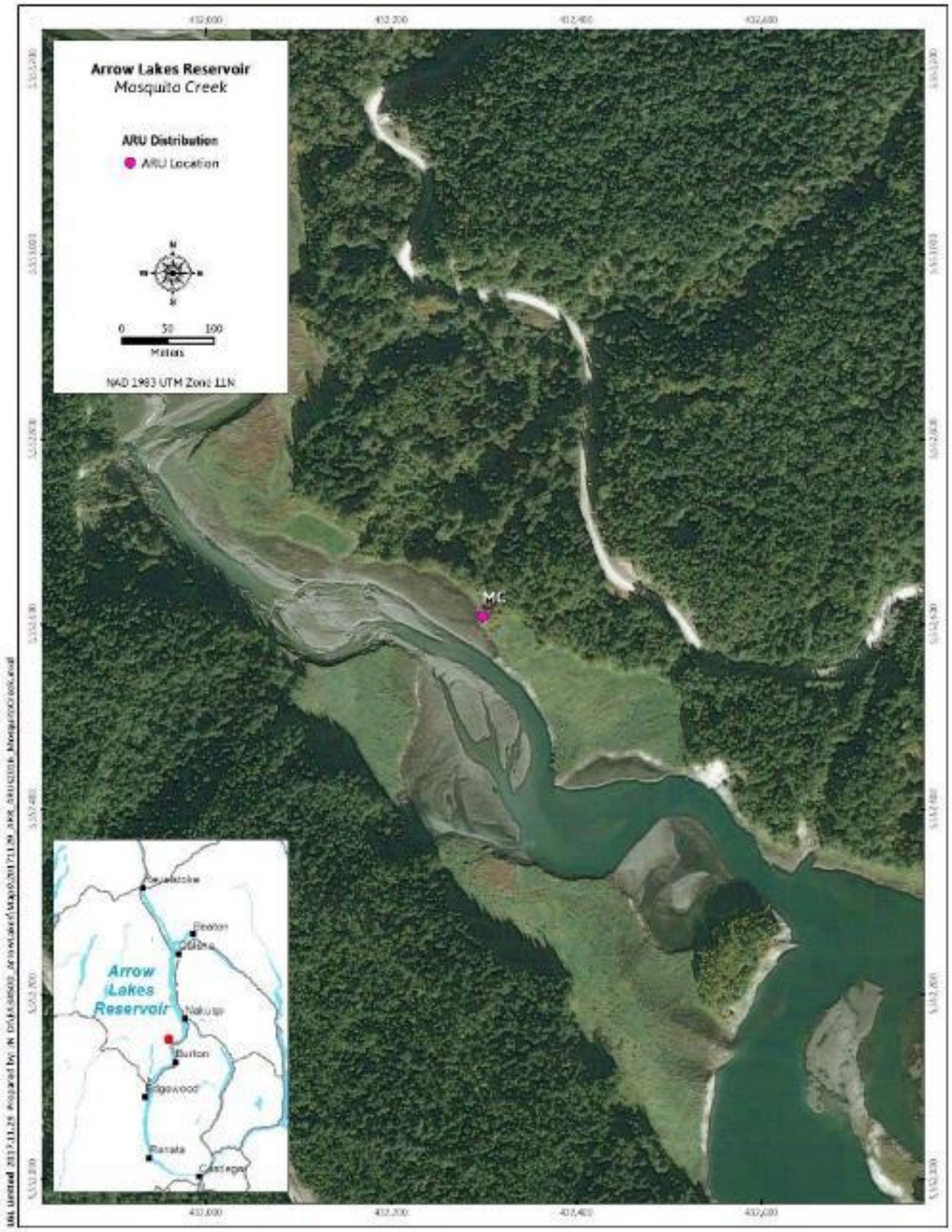


Map 9: Location of bat detector units installed at Burton Creek

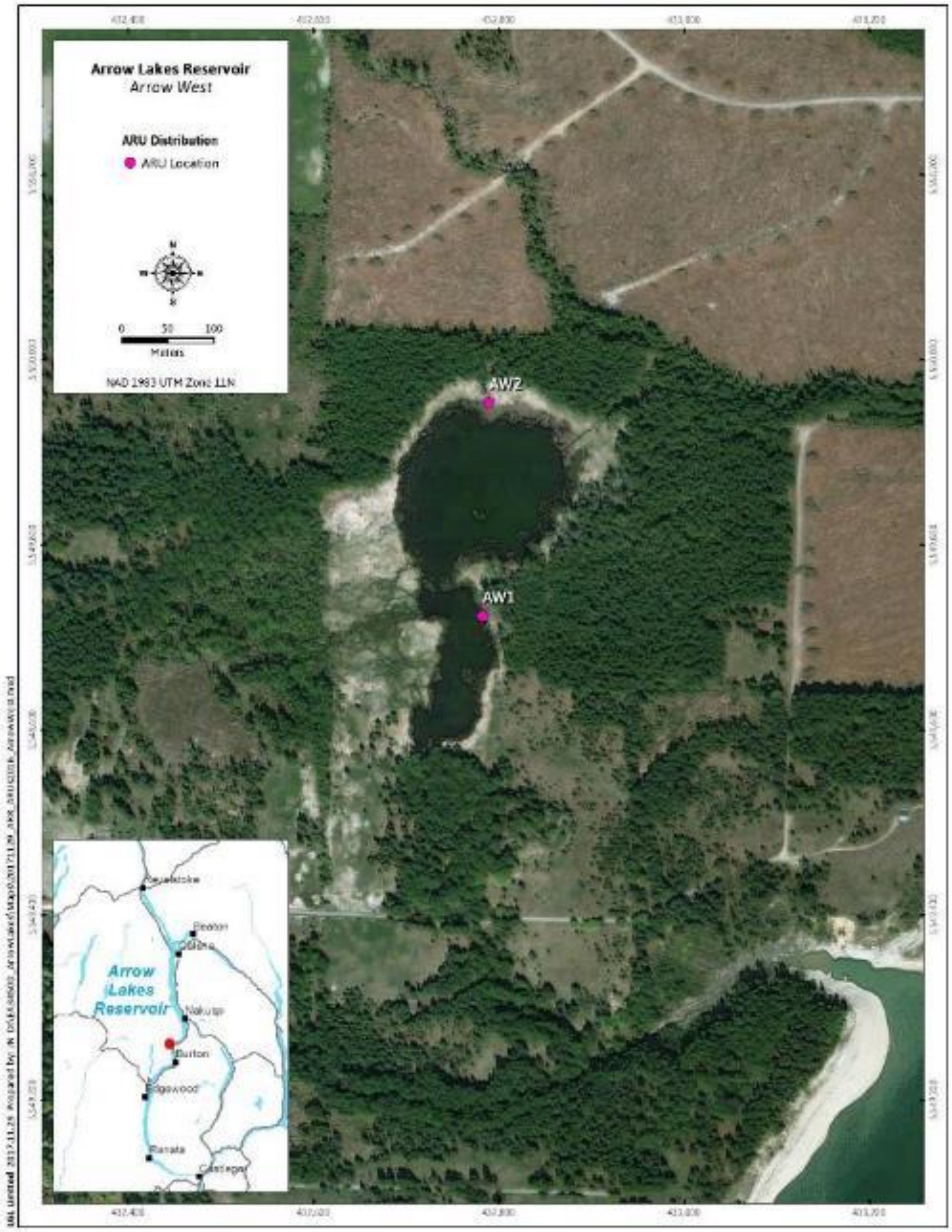


Map 10: **Location of bat detector units installed at Edgewood South**

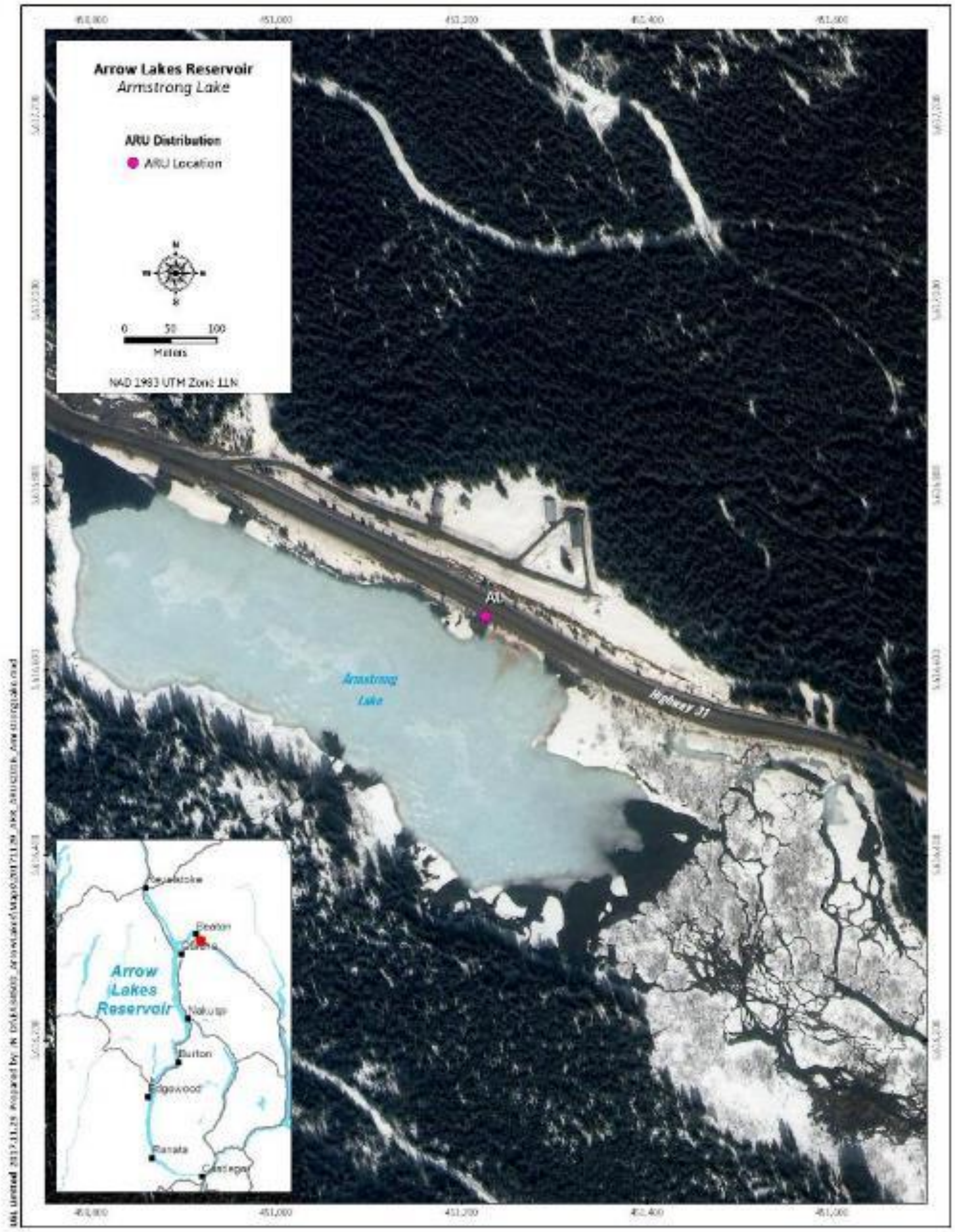
Map 11: Location of bat detector units installed at Lower Inonoaklin



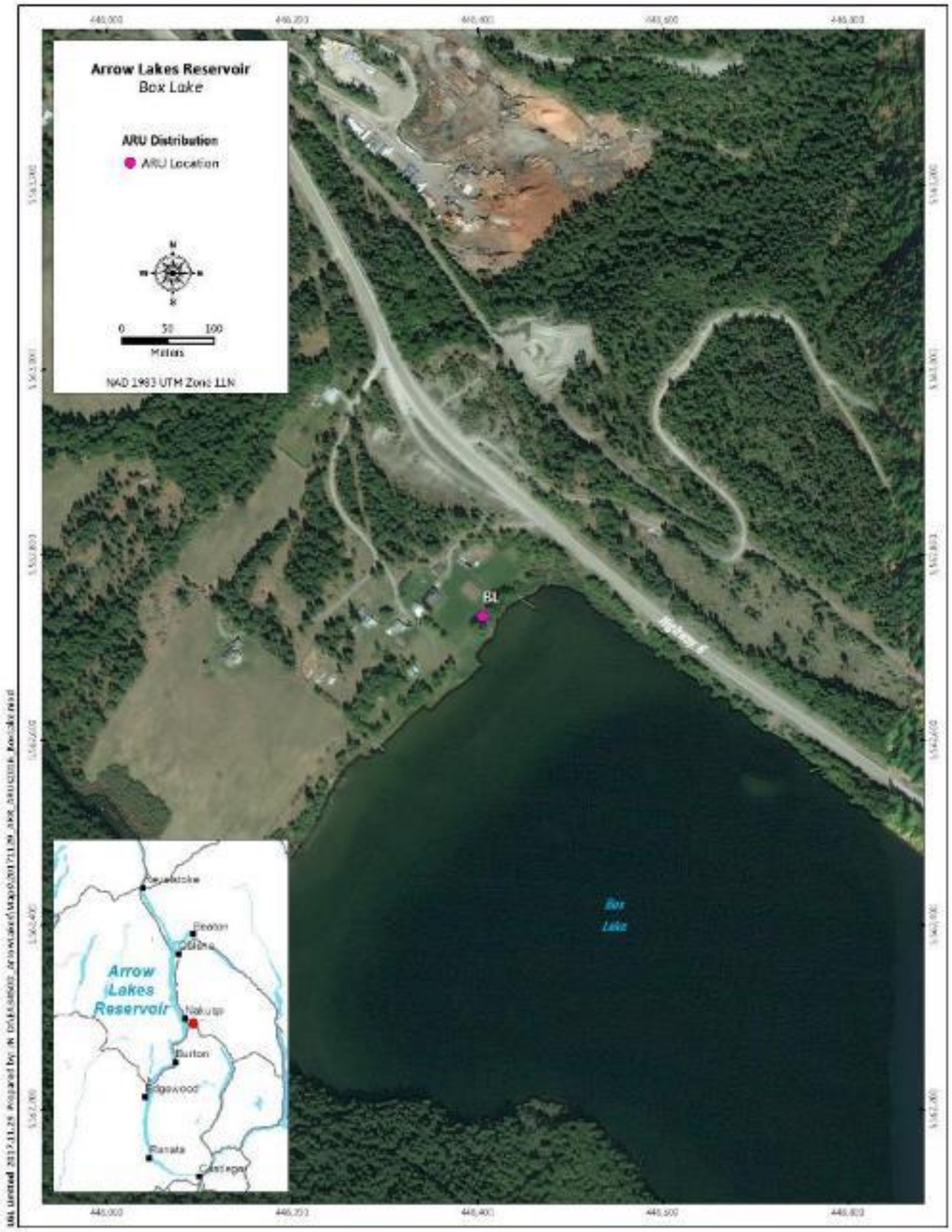
Map 12: **Location of the bat detector unit installed at Mosquito Creek**



Map 13: **Location of the bat detector units installed at Arrow West (non-reservoir site)**



Map 14: **Location of the bat detector unit installed at Armstrong Lake (non-reservoir site)**



Map 15: **Location of the bat detector unit installed at Box Lake (non-reservoir site)**

Appendix E: Supporting arthropod results

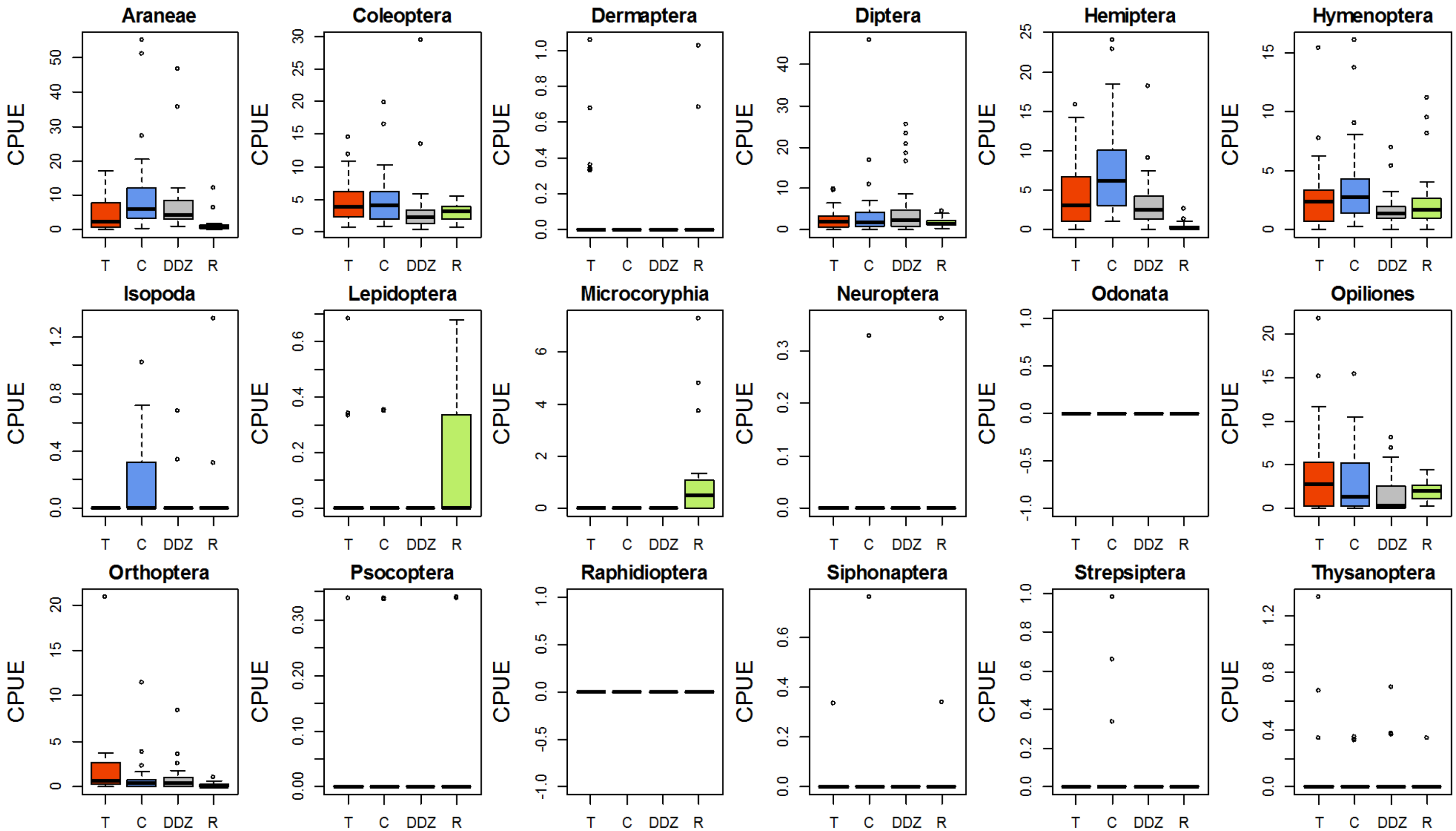


Figure 9-1: Arthropod catch per unit effort (CPUE) by taxonomic Order for pitfall traps in 2017. Study sites pooled; T= revegetation treatment, C= drawdown zone control, DDZ= pre-WPW location, and R= non-drawdown zone reference. Note: y-axis scales differ.

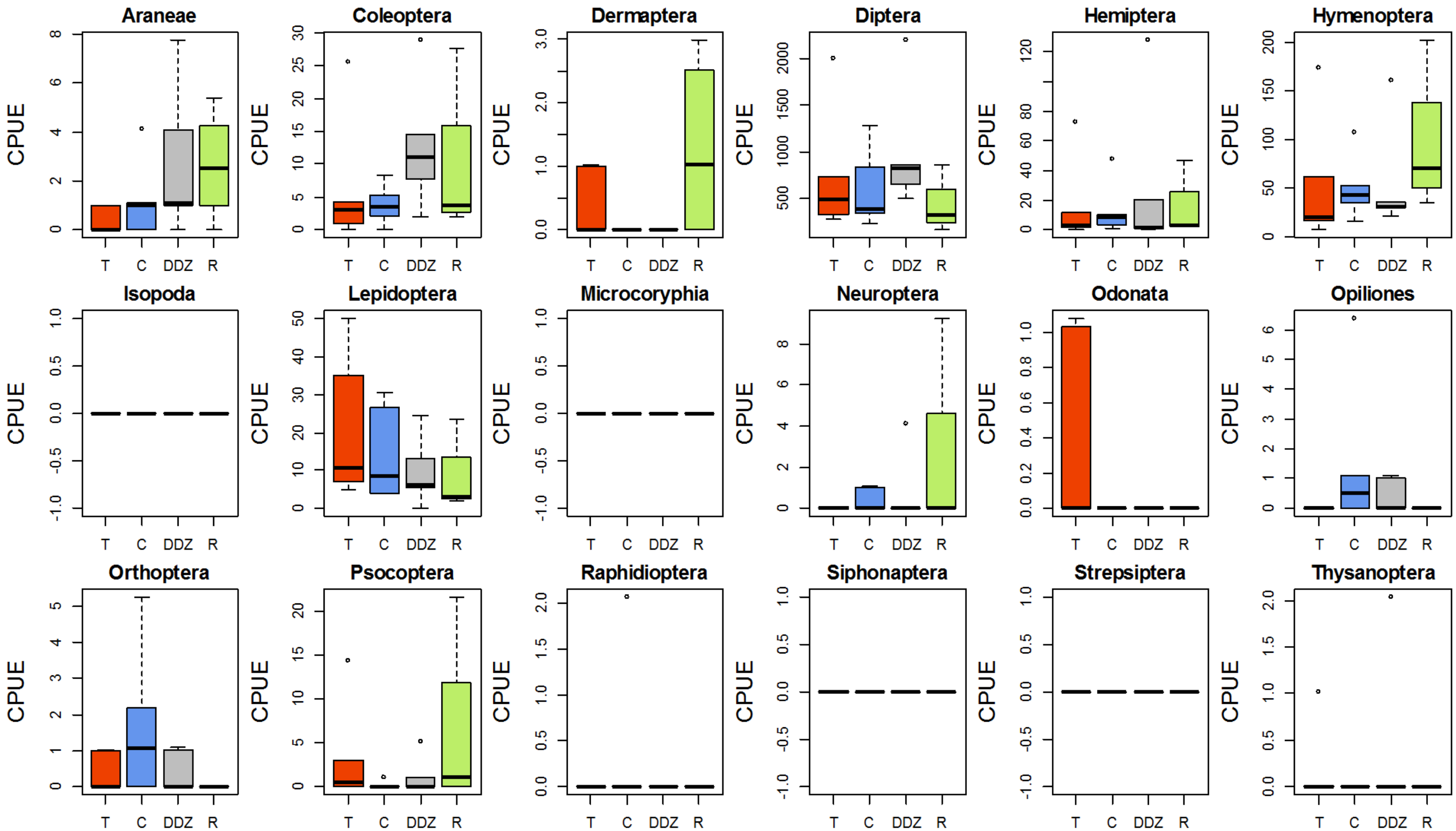


Figure 9-2: Arthropod catch per unit effort (CPUE) by taxonomic Order for Malaise traps in 2017. Study sites pooled; T= revegetation treatment, C= drawdown zone control, DDZ= pre-WPW location, and R= non-drawdown zone reference. Note: y-axis scales differ.

Appendix F: Supporting bird results

Table 9-1: Observations made during nest searching in 2016 and 2017 surveys, including nest location and fate. Site: BU: Burton Creek; DR: Drimmie Creek (Revelstoke Reach); EN: Edgewood North; ES: Edgewood South; LI: Lower Inonoaklin; MK: McKay Creek (Revelstoke Reach).

Treatment	Nest	Species	Reach	No. Eggs	Substrate	Height (m)	Success/Fail
	1	Cedar Waxwing	BU	.	Tree (Pine)	4.5	Unknown
	2	Cedar Waxwing	BU	.	Tree	>5	Unknown
	3	Chipping Sparrow	BU	N/A	N/A	.	Fledglings (no nest found)
	4	Chipping Sparrow	BU	4	Tree (cottonwood)	0.2	Unknown
	5	Lincoln's Sparrow	BU	5	Reed Canary Grass	0.1	Failed
TRT	6	Savannah Sparrow	BU	5	Ground	0	Unknown
	7	Spotted Sandpiper	BU	N/A	N/A	.	Fledglings (no nest found)
	8	Spotted Sandpiper	BU	4	Ground	0	Probable Success
TRT	9	Spotted Sandpiper	BU	4	Ground	0	Probable Success
CON	10	Spotted Sandpiper	BU	4	Ground	0	Probable Success
	11	Spotted Sandpiper	BU	4	Ground	0	Success
	12	Spotted Sandpiper	BU	4	Ground	0	Probable Success
	13	Chipping Sparrow	DR	0	Shrub (hardhack)	0.2	Failed
	14	Common Yellowthroat	DR	5	Shrub (willow)	0.25	Unknown
	15	Lincoln's Sparrow	DR	.	Ground (sedge)	0	Unknown
	16	Red-winged Blackbird	DR	1	Tree (cottonwood)	1.4	Failed (Inundated)
	17	Spotted Sandpiper	DR	2	Ground	0	Unknown
	18	Spotted Sandpiper	DR	.	Ground	0	Failed (Inundated)
	19	Spotted Sandpiper	DR	4	Ground	0	Unknown
	20	Spotted Sandpiper	DR	0	Ground	0	Unknown
	21	Willow Flycatcher	DR	0	Shrub (willow)	0.85	Unknown
	22	Wilson's Snipe	DR	1	Ground	0	Unknown
	23	Spotted Sandpiper	EN	3	Ground	0	Failed
	24	Spotted Sandpiper	EN	2	Ground	0	Success
	25	American Robin	ES	4	Tree (alder)	1.8	Unknown
	26	Cedar Waxwing	ES	0	Shrub (willow)	1.5	Unknown
TRT	27	Chipping Sparrow	ES	0	Tree (cottonwood)	0.3	Unknown
	28	Gray Catbird	ES	1	Shrub (willow)	1.75	Unknown
	29	Spotted Sandpiper	ES	4	Ground	0	Failed (Inundated)
	30	Spotted Sandpiper	ES	0	Ground	0	Failed (Inundated)
	31	Spotted Sandpiper	ES	4	Ground	0	Failed (Inundated)
	32	Spotted Sandpiper	ES	3	Ground	0	Failed (Inundated)
	33	Willow Flycatcher	ES	4	Shrub (willow)	1.4	Unknown
	34	Willow Flycatcher	ES	4	Tree (alder)	2.5	Unknown
TRT	35	Willow Flycatcher	ES	0	Shrub (cottonwood)	0.8	Failed
TRT	36	American Robin	LI	.	Tree (cottonwood)	.	Unknown
TRT	37	Cedar Waxwing	LI	0	Tree (cottonwood)	3	Abandoned
CON	38	Chipping Sparrow	LI	1	Shrub (snowberry)	0.5	Unknown
	39	Chipping Sparrow	LI	4	Shrub (rose)	0.8	Probable Success
	40	Common Yellowthroat	LI	N/A	N/A	.	Female carrying food (no nest found)
	41	Common Yellowthroat	LI	5	Reed Canary Grass	0.5	Failed (Inundated)
TRT	42	Nashville Warbler	LI	N/A	N/A	.	Fledglings (no nest found)
	43	Song Sparrow	LI	4	Reed Canary Grass	0.25	Probable Success
TRT	44	Spotted Sandpiper	LI	4	Ground	0	Probable Success
	45	Spotted Sandpiper	LI	2	Ground	0	Failed (Inundated)
	46	Spotted Sandpiper	LI	4	Ground	0	Unknown
	47	Willow Flycatcher	LI	4	Shrub (alder)	1.25	Unknown
	48	Willow Flycatcher	LI	4	Shrub (thimbleberry)	0.75	Unknown
	49	Willow Flycatcher	LI	.	Shrub (thimbleberry)	0.7	Unknown
	50	Cedar Waxwing	MK	5	Shrub (willow)	1.6	Unknown
	51	Cedar Waxwing	MK	.	Shrub (willow)	4.75	Unknown
	52	Willow Flycatcher	MK	0	Shrub (willow)	0.9	Unknown
	53	Yellow Warbler	MK	.	Shrub (willow)	3	Unknown
	54	Yellow Warbler	MK	4	Shrub (willow)	1.9	Probable Success
	55	Yellow Warbler	MK	0	Shrub (willow)	2.8	Failed
	56	Yellow Warbler	MK	3	Shrub (willow)	2.1	Unknown