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 6

Reference: CLBMON-11B1

Final Annual Report

Study Period: 2015

Okanagan Nation Alliance, Westbank, BC
and
LGL Limited environmental research associates
Sidney, BC

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KINBASKET AND ARROW LAKES RESERVOIRS

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




2015 Annual Report

Final

Prepared for

BC Hydro Generation

Water Licence Requirements
6911 Southpoint Drive
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From left to right: Beaton Arm beaver ponds; Eastern Kingbird (*Tyrannus tyrannus*); western tiger swallowtail (*Papilio rutulus*); and sedge plug at Burton Creek © Virgil C. Hawkes, LGL Limited.

EXECUTIVE SUMMARY

CLBMON-11B1, initiated in 2009, is a long-term wildlife monitoring project that aims to assess the efficacy of revegetation prescriptions (i.e., CLBWORKS-2) in enhancing the suitability of habitats in the drawdown zone of Arrow Lakes Reservoir for wildlife, and to develop a minimum of three wildlife enhancement prescriptions that can be implemented in the drawdown zone to further improve habitat suitability (i.e., CLBWORKS-29B).

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

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

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

Overall, we failed to detect a clear relationship between revegetation prescription treatments and the biomass of arthropods or the relative abundance of arthropods and songbirds. Among control and treatment polygons, average arthropod biomass of Malaise samples were similar for all sites, except at Edgewood south, where treatment Malaise biomass was greater than control on average. Pitfall trap biomass was lower for treatments than paired controls at Edgewood South, Edgewood North, and the Burton sedge plug treatment (BU02), but was greater for the live stake treatment at Burton (BU01) than the paired control area.

Arthropod and Songbird assemblages distinctly partitioned along an environmental gradient representing the drawdown zone (control, treatment, and drawdown zone habitats) and adjacent upland (reference) habitats. These assemblage groupings were consistent for years 2010, 2011, 2013, and 2015. More time may be required to assess how species richness, biomass, and relative abundance change as a result of the implementation of the revegetation prescriptions.

Songbirds and arthropods continue to be suitable indicators to assess changes in habitat quality induced by the revegetation prescriptions. This evidence is based on the persistence of distinct drawdown zone and upland songbird and arthropod communities and on the relationships between songbirds and their arthropod prey. Although density dependent events appear to be affecting the biomass of arthropods a temporal data set consisting of multiple years should provide a smoothing effect and an indication of how arthropod biomass is changing and whether that change can be correlated to treatments.

Ungulate use of the drawdown zone does not appear to be related to the revegetated areas. This is based on aerial surveys in 2010 and 2011 and pellet plot sampling in 2011, 2013, and 2014. These plots were counted and cleared in 2013 and 2014 and results indicated that deer were using the drawdown zone to some degree, but habitat use did not vary between control and treatment sites. Continued monitoring of ungulates as an indicator of revegetation effectiveness is not recommended. Future sampling for ungulates (via aerial surveys or pellet plots) is not recommended because of the limited influence the revegetation prescriptions are likely to have on ungulate populations. Evidence of use can be obtained by recording ungulate sign when sampling for other taxa.

Monitoring the use of the drawdown zone by bats has resulted in the documentation of 12 species of bat occurring in mid- and lower Arrow Lakes Reservoir. The relationship between bats and revegetation prescriptions has been difficult to assess, mainly because the data we collect is an indication of species presence at each study area and not necessarily correlated with a specific habitat type. Refinements to bat sampling are proposed to sample within treatment and control areas in future years.

Our ability to address each of the management questions is summarized below. The methods used are appropriate for collecting data that can be used to answer certain questions. For others, additional approaches may be required. For example, to answer questions regarding songbird productivity, nest searches are suggested. In other cases, increasing the total area or number of areas revegetated would assist with problems associated with small sample size and small revegetation treatment areas. Continued monitoring of arthropod, songbird, and bat, populations in the drawdown zone should provide the necessary information to answer most management questions. Modifications to the study are suggested that will improve our ability to answer the management questions. Until the physical works are implemented in mid- and lower Arrow Lakes Reservoir, we will not be able to answer questions regarding their effectiveness.

MQ	Able to Address MQ?	Scope		Sources of Uncertainty
		Current supporting results	Suggested modifications to methods where applicable	
1. Are the revegetation and the wildlife physical works projects effective at enhancing wildlife habitat in the drawdown zone?	Inconclusive	There is evidence of species-specific responses to revegetated areas (more bird nests) but results for other taxa are inconclusive. The data indicate that wildlife is using all habitat types, but current results show little difference between control and revegetation treatment plots. Physical Works: Unknown. Not implemented.	• Pair autonomous acoustic monitors (bats) to sample control and treatment areas simultaneously • Focus sampling on areas where revegetation prescriptions are most successfully established	• Lack of appropriate baseline (sampling did not occur prior to the application of the revegetation prescriptions) • Natural annual population variation and seasonality • Proximity of treatments to adjacent upland habitat • Lack of replication • Lack of measured success of revegetation program • Bi-annual sampling • Variable reservoir operations • Physical works have not been implemented
2. If revegetation and the wildlife physical works projects enhance wildlife habitat in the drawdown zone, to what extent does the revegetation program and the wildlife physical works projects increase the productivity of habitat in the drawdown zone for wildlife?	Inconclusive	It is unclear if the revegetation prescriptions are effectively improving wildlife habitat. In general, no multi-year trend has been observed for biomass values between control and treatment areas within sites. Wildlife physical works projects are in progress and have yet to be implemented and monitored.	• Increased frequency of sampling (i.e., annually) • Include nest searches to study songbird productivity • Pair autonomous acoustic monitors to sample control and treatment areas simultaneously	• Lack of appropriate baseline (sampling did not occur prior to the application of the revegetation prescriptions) • Natural annual population variation and seasonality • Lack of replication • Success of revegetation program • Bi-annual sampling • Variable reservoir operations • Physical works have not been implemented • Lack of productivity surveys for songbirds (i.e., nest searches)
3. Are some methods or techniques more effective than others at enhancing wildlife habitat in the drawdown zone?	Inconclusive	The application of treatment prescriptions in the drawdown zone does not support a treatment-specific assessment. The prescriptions applied were too small, not well-replicated, nor were they stratified by site.	• Consider adding replicates of certain revegetation prescriptions at some sites • Increase the size (total area treated) of some existing revegetation areas	• Lack of appropriate baseline (sampling did not occur prior to the application of the revegetation prescriptions) • Natural annual population variation and seasonality • Lack of replication • Success of revegetation program • Variable reservoir operations • Physical works have not been implemented

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

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ACRONYMS AND DEFINITIONS

To ensure that readers of this report interpret the terminology used throughout, the following definitions are provided. Definitions are presented in a logical, not alphabetical, order. These definitions follow those in Hawkes et al. (2011a).

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

Within study sites, sampling was conducted in control, treatment, drawdown zone, and reference areas (collectively referred to as habitat types). These terms 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.

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

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

Reference: sampling location outside of the drawdown zone (> 440.1 m ASL) adjacent to control and treatment areas. 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. Reference sites could also be areas within the drawdown zone that represent a desired condition.

Experimental Block: pairing of a treatment site with a control site. The experimental block established at reaches 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, and navigation and flood control. The goal of the Water Use Plan is to accommodate these values through operational means (i.e., patterns of water storage and release) and non-operational physical works in lieu of changing reservoir operations to address specific interests. During the Water Use Planning process, the Consultative Committee supported the implementation of physical works (revegetation and habitat enhancement) in the mid-Columbia River in lieu of changing reservoir operations to help mitigate the impact of Arrow Lakes Reservoir operations on wildlife and wildlife habitat. In addition, the Consultative Committee recommended the use of monitoring to assess the effectiveness of these physical works in enhancing habitat for wildlife.

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

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

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

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

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

2.0 OBJECTIVES AND MANAGEMENT QUESTIONS

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

In addition to assessing the overall effectiveness of the revegetation and wildlife physical works projects, CLBMON-11B1 will facilitate an adaptive management approach to habitat enhancement. Adaptive management is an iterative process designed to improve the rate of learning with respect to managing complex systems (Taylor et al. 1997, Murray and Marmorek 2004). The process incorporates an explicit acknowledgement of uncertainties and knowledge gaps about the response of the system to management actions, and attempts to reduce those uncertainties through structured monitoring of those management actions (e.g., treatments). The underlying tenet of “learning by doing” lends itself well to ecosystem restoration and habitat enhancement. This approach has been embraced by practitioners of ecosystem restoration (see Douglas 2003, Clewell et al*.* 2005, Patten 2006).

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

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

Rationale: “There is uncertainty about current utilization of the drawdown zone by wildlife species and the effects of reservoir operations. Monitoring will inform on the effects of revegetation efforts in Kinbasket and Arrow Lakes Reservoirs on

[1] CLBMON-11B includes two of three modules (1 and 2). Module 3 is a stand-alone project that focuses specifically on Revelstoke Reach.

wildlife utilization patterns and the effectiveness of Arrow Lakes Reservoir physical works on wildlife habitat quality and quantity".

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

The combined objectives of CLBMON-11B (modules 1 and 2) and CLBWORKS 29B (collectively referred to as CLBMON-11B1) are as follows:

1. Develop a monitoring program to assess the effectiveness of the revegetation program (CLBWORKS-2) and wildlife physical works projects (CLBWORKS-30) in enhancing wildlife habitat in the drawdown zone of Arrow Lakes Reservoir.
2. Monitor the appropriate biological indicators and response variables to assess the effectiveness of the revegetation and wildlife physical works programs in enhancing wildlife habitat in the drawdown zone.
3. Provide recommendations on the effectiveness of the revegetation program and wildlife physical works projects in improving habitat for wildlife in the drawdown zone.
4. Identify high-value habitat along the drawdown zone of the lower and middle reaches of the Arrow Lakes Reservoir for protection.
5. Identify habitat enhancement opportunities along the drawdown zone of the lower and middle reaches of the Arrow Lakes Reservoir.
6. Provide recommendations for enhancing or protecting high-value wildlife habitat along the drawdown zone of the lower and middle reaches of the Arrow Lakes Reservoir.
7. Prepare a minimum of three habitat enhancement/restoration plans.

2.1 Management Questions

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

This monitoring program will address three management questions:

1. Are the revegetation and the wildlife physical works projects effective at enhancing wildlife habitat in the drawdown zone?
2. If revegetation and the wildlife physical works projects enhance wildlife habitat in the drawdown zone, to what extent does the revegetation program and the wildlife physical works projects increase the productivity of habitat in the drawdown zone for wildlife?

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

2.2 Management Hypotheses

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

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

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

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

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

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

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

HA_2: Wildlife physical works does not change wildlife use of the drawdown zone.

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

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

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

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

HA_3: The methods and techniques employed do not result in changes to wildlife habitats in the Arrow Lakes Reservoir drawdown zone.

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

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

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

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

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

2.3 Key Water Use Decisions Affected

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

3.0 STUDY AREA

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

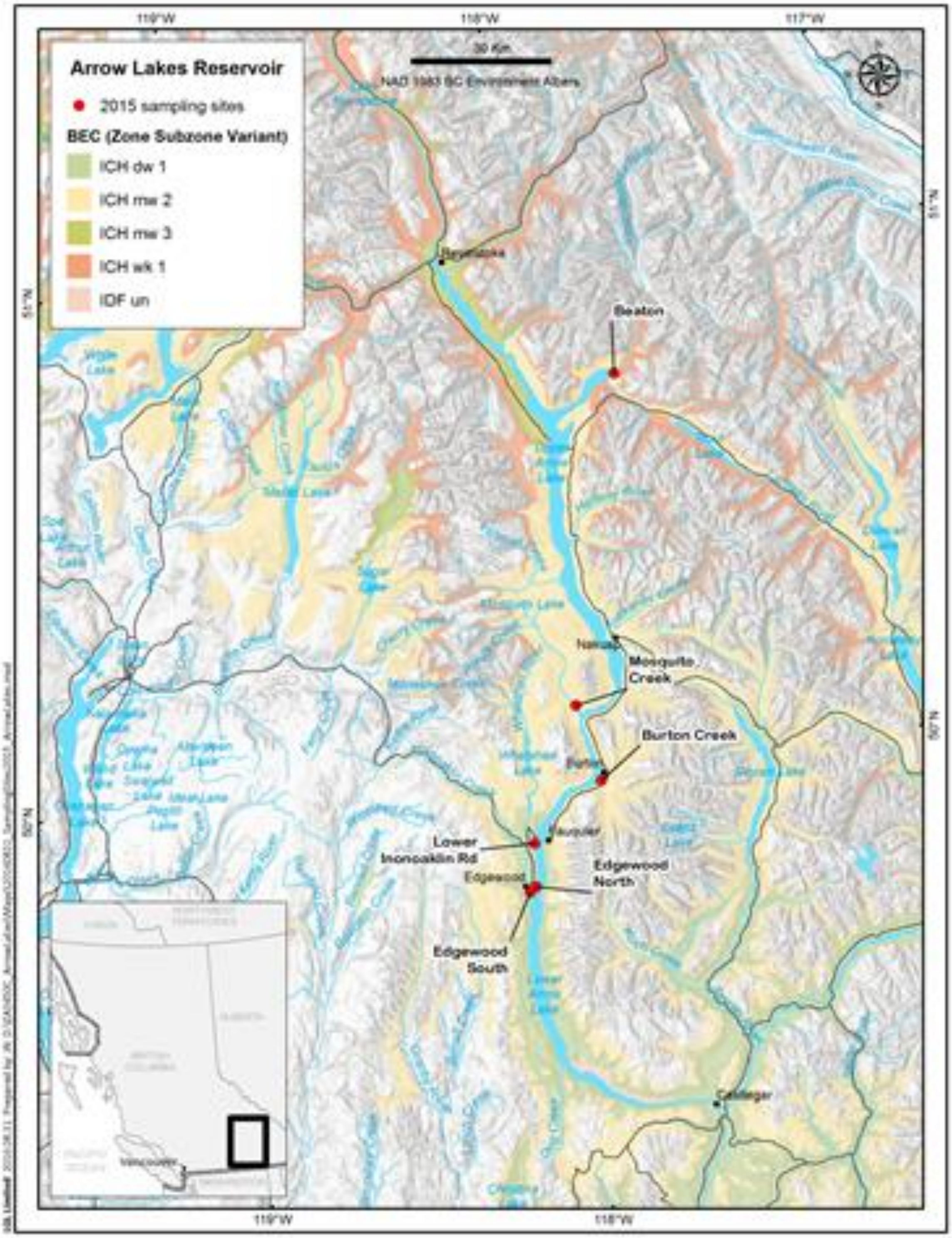

Figure 3-1: Location of 2015 sampling sites within Arrow Lakes Reservoir in B.C.

For CLBMON-11B1, the area of interest within Arrow Lakes Reservoir is the drawdown zone between Beaton Arm and Castlegar (Figure 3-1). For certain species groups (e.g., songbirds and terrestrial arthropods), those portions of the drawdown zone where revegetation prescriptions were applied under CLBWORKS-2 are the focal areas. In 2015, sampling did not occur at East Arrow Park due to lack of establishment of revegetation treatments. Until it was discontinued prior to 2015, the entire drawdown zone from Revelstoke to Castlegar on both the east and west sides of the reservoir comprised the mammal (e.g., ungulates and winter furbearers) study area.

In 2010, seven areas within the drawdown zone of Arrow Lakes Reservoir were selected for monitoring (vs. six in 2009; Figure 3-1). Lower Inonoaklin Road was added after 2009. Site selection was based on those areas treated under CLBWORKS-2 (Keefer et al. 2009), on areas within the drawdown zone that will not be treated under CLBWORKS-2 where potential wildlife enhancement projects could occur (e.g., Lower Inonoaklin), and areas that represent habitats in the drawdown zone that could be considered climax communities (relative to those that could develop in the drawdown zone). These sites were monitored again in 2013 and 2015.

Table 3-1: List of sites sampled in each year from 2009 to 2015. "X": all taxa were sampled; "O": songbird surveys only; "-": no sampling occurred.

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

4.0 METHODS

4.1 Revegetation Effectiveness Monitoring

Revegetation prescriptions (CLBWORKS-2) were applied between 2008 and 2011 and the total area revegetated per year ranged from 2.13 ha in 2008 to 36.22 ha in 2009. The plug seedling prescription was the most commonly applied prescription (39.84 ha) followed by hand-planted live stakes (23.31 ha). All other prescriptions were either applied either over relatively small areas or in one year only. Both plug seedling and hand-planted live stakes prescriptions were used in all reaches sampled for CLBMON-11B1. Examples of the types of revegetation prescriptions applied in the drawdown zone of Arrow Lakes Reservoir are detailed in Hawkes et al. (2014). A glossary of terms, including treatment prescriptions, is given in the Acronyms And Definitions section.

The timing of the 2015 sampling sessions (Table 5-1) coincided with the period that terrestrial arthropods, birds, and bats were active. Sampling occurred during similar periods as in previous years.

4.2 Songbirds

4.2.1 Songbird point count surveys

Songbirds were surveyed between June 10 and July 14, 2015. Time-constrained, variable-radius[2] point count surveys were used to assess the diversity and relative abundance of songbirds (Ralph et al. 1995). The timing of the songbird surveys (mid-June to mid-July) coincided with the height of the breeding season at which time all locally breeding birds are on territory and are highly vocal, enabling surveyors to document the number and diversity of breeding birds. Two visits to each point count were scheduled. Surveys commenced at sunrise and ended within ~4 hours of sunrise (Ralph et al. 1995). Songbird surveys were done during favourable conditions only (i.e., no heavy wind or precipitation) to standardize surveys and minimize variable detections associated with sub-optimal environmental conditions. All songbird surveys conformed to the provincial standard (RIC 1999).

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

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

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

In 2015 we continued to sample songbirds using the 75 m variable radius point count method, but used only songbirds documented within 30 m of the point count centre when investigating potential treatment effects (which follows the approach taken in 2011; Hawkes et al. 2012).

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

A total of 91 variable radius point counts were sampled in 2015 (Table 4-1). This is lower than previous years (which ranged from 106 to 123 point counts) owing to the elimination of East Arrow Park as a study area. Most point counts were visited twice; some point counts could only be visited once due to high water elevations. Point counts that were visited twice were typically surveyed once in June and once in July, to record locally breeding bird species and capture within-year variability in species presence and detections. Survey effort varied by site, with the number of point counts established per site based on the amount of area available for sampling. The highest number of point counts sampled in 2015 was in Burton Creek. Revegetation prescriptions were not applied at either Mosquito Creek or Beaton Arm, therefore point counts were established only in drawdown and reference (upland) habitats at those locations.

Table 4-1: Number of point counts sampled per site, and type of habitat in 2015. Sites are ordered from south to north in the Arrow Lakes Reservoir

Reach	Control	Drawdown Zone	Reference	Treatment	Total
Beaton Arm		5	9		14
Burton Creek	6	5	9	6	26
Edgewood North	2	2	4	4	12
Edgewood South	3	1	6	3	13
Lower Inonoaklin		1		7	8
Mosquito Creek		9	9		18
Total	11	23	37	20	91

Maps depicting the location and distribution of songbird point count stations for each site and habitat sampled in 2015 are provided in Appendix B.

4.2.2 Nesting Evidence

Nest searches were completed within the drawdown zone and adjacent habitat at all sites. Limited survey effort was given to upland (reference) habitats, as we opted to dedicate searching time to the revegetation treatment and control areas. However, when an upland nest was found opportunistically, it was recorded and monitored. 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.

4.3 Terrestrial Arthropods

4.3.1 Arthropod Collection

Terrestrial arthropods were sampled with pitfall trap arrays and Malaise traps using methods consistent with those described in 2011 and 2013 (Hawkes et al. 2011, 2014) and provincial RIC standards (1998). In 2015, we sampled in June and July to coincide with songbird sampling versus sampling in May and June of 2013 and May, June, and July of 2011. As in 2013, no light trapping was performed. As in previous years, not all combinations of site and habitat type were sampled (Table 4-2). For e.g., East Arrow Park was not sampled for arthropods due to lack of revegetation success, an upland reference site was not sampled at Edgewood North, and revegetation prescriptions were not applied to Mosquito Creek or Beaton Arm.

Five pitfall arrays were established in control, treatment, and reference locations at all sites. Pitfall arrays were comprised of three 473 mL clear plastic Amcor® food cups inserted into the ground at 1 m spacing within a predetermined, randomly selected sampling location. Each sampling location was randomly selected within each treatment and control polygon in GIS by first overlaying a 5 m x 5 m grid on the polygon and then randomly selecting each grid cell for sampling.

One Malaise trap was established in control, treatment and reference locations at all sites. Sample locations were selected randomly using the same method as pitfall trap site selection.

Traps were filled with ~100 mL of preservation fluid (Prestone® LowTox Antifreeze/Coolant). After approximately 48 hours, samples were collected for assessments of arthropod biomass (‘biomass samples’), with contents of individual pitfall traps pooled within each array to generate five biomass pitfall trap samples and one malaise trap sample for each habitat polygon. Traps were immediately serviced and filled with preservation fluid. A second collection was made after an additional ~24 hours of sampling time. These one-day samples were collected for assessments of arthropod diversity (‘diversity samples’). Similarly, contents from individual pitfall traps were pooled into one pitfall trap sample for each array, resulting in five pitfall diversity samples and one malaise diversity sample per habitat polygon.

This sampling protocol was repeated in two survey periods from June 10 to 17 and from July 10 to 17, 2015. Total sampling effort was 546 trap nights (Malaise: 91 trap nights; pitfall: 455 trap nights; Table 4-2). Differences in trap nights were related to a setup delay at Burton Creek and non-functional traps caused by weather or animal disturbance. Malaise and pitfall traps were operational for a total of 11,219.5 hours in 2015 (Table 4-2). In general, similar effort was expended between control, treatment, and reference areas at each site for both Malaise and pitfall traps.

Maps depicting the location of pitfall and Malaise traps in 2015 are provided in Appendix A.

Table 4-2: Distribution of trap nights by site, sampling method, and habitat type in the Arrow Lakes Reservoir. Sites with the same number (e.g., BU01 C and BU01 T) were paired samples. See Section 4.0 for definitions of habitat types.

		Trap Nights per Method		
Reach Name	**Treatment & Site**	**Malaise**	**Pitfall**	**Total**
Beaton Arm	Drawdown Zone	6	30	**36**
	Reference	6	30	**36**
Beaton Arm Total		**12**	**60**	**72**
Burton Creek	BU01 C	4	20	**24**
	BU01 T	3.5	20	**23.5**
	BU02 C	6	31	**37**
	BU02 T	5.5	30	**35.5**
	Reference	5	25	**30**
Burton Creek Total		**24**	**126**	**150**
Edgewood North	EWN C	5.5	30	**35.5**
	EWN T	5.5	30	**35.5**
Edgewood South	EWS C	6	30	**36**
	EWS T	6	30	**36**
	Reference	6	29.5	**35.5**
Edgewood Total		**29**	**149.5**	**178.5**
Mosquito Creek	Drawdown Zone	6	30	**36**
	Reference	5.5	30	**35.5**
Mosquito Creek Total		**11.5**	**60**	**71.5**
Total (all reaches and treatments)		**76.5**	**395.5**	**472**

4.3.2 Sample Processing and Identification

The three day biomass samples were weighed and placed in a drying oven for 48 hours to dry. The dried samples were weighed again to obtain the dry weight of each sample. The biomass of each taxon group was extrapolated from the composition given by the one day samples (see Hawkes et al. 2012, 2014). The biomass associated with each trap type, site, and habitat type was kept separate for comparative purposes. The biomass samples were not tallied, sorted, or identified in 2015 due to the time intensive nature of this work.

With the aid of specialists, arthropods from one day samples were counted and dominant taxa groups were identified to lowest taxonomic level possible. Flies (Diptera), beetles (Coleoptera), and bees, wasps and ants (Hymenoptera) were placed to family. Grasshoppers and kin (Orthoptera), spiders (Araneae) were identified to species because of their potential use as indicators to assess habitat changes associated with the application of revegetation prescriptions in the drawdown zone of mid- and lower Arrow Lakes Reservoir.

4.4 Terrestrial Mammals

Terrestrial mammal observations (visual sightings, wildlife signs) were documented in control, treatment, and reference sites in 2015, through incidental observations. The location of species observed, and mammal sign (e.g., bones, hair, and scat) in the drawdown zone and reference locations were recorded. This general approach was consistent with the methods used by Hawkes et al. (2010, 2011a, 2012, 2013). We also documented the location of unique wildlife habitat features, such as mineral licks or animal dens. Occasionally, small mammal bycatch occurred during arthropod pitfall trapping. Any specimens collected in

Whirl-Pak® sampling bags, with preservative, labelled and stored in a freezer until identified using a microscope and key (Naughton 2012).

Following the recommendations of Hawkes et al. (2012), and further study by Adama and Hawkes (2015), the pellet plot component was discontinued in 2013, until future physical works or revegetation prescriptions specifically address ungulate habitat enhancement. Based on recommendations in Hawkes et al. (2012), winter mammal surveys were not conducted in 2013 or 2015.

4.5 Bats

There are potentially 12 bat species in the West Kootenays, but the number of live-capture studies has been insufficient to confirm the presence of at least one of those [Western Small-footed Myotis (*Myotis ciliolabrum*)]. Five species that could occur in the study area are of conservation concern at the provincial and/or national level. In BC, Townsend's Big-eared Bat (*Corynorhinus townsendii*), Western Small-footed Myotis, Northern Myotis (*M. septentrionalis*), and Fringed Myotis (*M. thysanodes*) are blue-listed by the Conservation Data Centre (CDC), which is a status assigned to species that are particularly sensitive to impacts from human activities or natural events (B.C. CDC 2013). Federally, Northern Myotis and Little Brown Myotis (*M. lucifugus*) were emergency listed under 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 4-3: Provincial and national status of bat species that potentially occur in the Lower and Mid-Arrow Lakes area

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

To study bat presence and distribution over and adjacent to the drawdown zone, Wildlife Acoustics SM2BAT and SM2BAT+ autonomous recording units were deployed from mid-June to early September. Each unit was programmed with a schedule to document bats during two periods: (1) half an hour before sunset for 5.5 hours, and (2) an hour before sunrise for 1.5 hours, for a total of 7 hours per 24 hour period. Bat detectors were deployed at Edgewood South, Edgewood North, Lower Inonoaklin, Burton Creek, Mosquito Creek, and Beaton Arm. At both Edgewood sites, Lower Inonoaklin, and Burton Creek, bat detectors were situated in or angled toward a live stake treatment (EPL, EPL/HPL, or HPL) prescription. Bat detectors sampled upland reference sites at Burton and Mosquito Creeks, while Beaton Arm and Mosquito Creek had detectors sampling control (untreated) drawdown zone areas. At Beaton Arm, the control area selected was near the lower beaver ponds, but angled towards the drawdown area

Under ideal conditions the bat detectors will detect 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.

As several bat species overlap in their frequency ranges, it is difficult to confidently differentiate some species based only on the frequencies recorded (Table 4-4; also see Betts 1998 and Lausen et al. 2014). Bat presence and activity was therefore assessed by analysing the recordings from each bat detector using Kaleidoscope Pro v. 3.1.1 (Wildlife Acoustics, Maynard, MA). Kaleidoscope is an integrated suite of bat data tools designed to quickly convert files, sort and categorize bat data by species, verify findings, visualize the data collected and easily transform it into reports. Despite the utility of this software, there is the potential for acoustic signatures to overlap between similar species, thus we present our bat detections as “potential” rather than definitive (Kruger and Peterson 2008, Lausen et al. 2014).

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

Frequency (kHz)	*Eptesicus fuscus*	*Lasiurus cinereus*	*Lasionycteris noctivagans*	*Myotis evotis*	*M. lucifugus*	*M. septentrionalis*	*M. volans*
Characteristic frequency (*ƒ*c)	27 - 31	19 - 24	25 - 28	33 - 37	40 - 43	40 - 46	40 - 44
Highest apparent frequency (hi *ƒ*)	49 - 66	20 - 39	36 - 53	71 - 97	70 - 94	90 - 116	77 - 100
Lowest apparent frequency (lo *ƒ*)	26 - 30	19 - 24	24 - 27	26 - 30	35 - 40	32 - 41	34 - 39

4.6 Data Analyses

In general, data analyses followed those performed in 2013 (Hawkes et al. 2014), 2009 (Hawkes et al. 2010), and 2010 (Hawkes et al. 2011). Most of the results reported summarize the data collected in 2015 and do not represent a detailed assessment of temporal trends. The analyses performed in 2015 aimed to do the following:

1. continue to characterize the fauna (i.e., songbirds, arthropods, mammals, and amphibians and reptiles) in the drawdown zone of mid- and lower Arrow Lakes Reservoir;
2. compare (where possible) the relative abundance and species richness of songbirds and arthropods among the various combinations of sites and habitat types between years;
3. relate the biomass of certain orders of arthropods (those eaten by insectivorous songbirds) calculated for 2013 to the songbird species that would prey on those orders; and

4. determine if the songbird and arthropod assemblages associated with drawdown and adjacent upland habitats documented in previous years (2009, 2010, 2011, and 2013) persisted in 2015.

4.6.1 Terrestrial Arthropods

Arthropod data were compared among habitats within each site as described previously (Hawkes et al. 2010, 2011a, 2012, 2014). We standardized our taxonomic classifications for use in analyses, according to the arthropod group and consistency in level of identification. As such, taxa were constrained to species for Araneae and Orthoptera, family for Diptera, Hymenoptera, and Coleoptera, and order for all other arthropods. Any records not meeting these classifications were excluded for analyses (e.g., spiders identified to Genus-level only were excluded).

Relative abundance, richness, and biomass were assessed as per Hawkes et al. (2014). Relative abundance was calculated as catch-per-unit-effort (CPUE), equal to the number of arthropods caught per trap, standardized to a 10-hour trapping period. Similarly, richness was calculated as the total number of arthropod taxa (e.g., spider species, beetle families, arthropod orders) caught per trap, standardized to a 10-hour trapping period. Total richness was also shown for the 2015 pitfall and Malaise trap data. Average biomass, in milligrams per hour, was assessed by habitat type and site in bar graphs (with 90% confidence intervals).

For corrected arthropod richness, statistical tests were performed with two-way unbalanced crossed-factor ANOVA tests with 9999 permutations using Pierre Legendre's function 'anova.2way.unbalanced.R' (Legendre, 2015). This method computes ANOVA test statistics with distance-based redundancy analysis (RDA; Anderson and Legendre 1999; Legendre and Anderson 1999). Several significance tests were computed in series for comparisons among habitat types, among years, among sites and years (where data was subset for each habitat type). P-values were not adjusted for multiple comparisons. Results of statistical tests were considered significant at $\alpha=0.05$.

Composition and assemblage similarity

Arthropod assemblages (e.g., beetle families, spider species) were assessed by Principal Coordinates Analysis (PCoA), and the computation of Kendall coefficient of concordance *W*, K-means partitioning, and Principal Components Analysis (PCA). All analyses were computed in the R language (R Core Team 2016) using the vegan package for community ecology (Oksanen et al. 2016).

The identification of clusters of taxa allows an investigation of the ecological requirements that are common to the cluster rather than evaluating the ecological needs of each species individually. Ordination and partitioning analyses allow resemblance of these community patterns. PCoA ordination analysis is useful in ecology, where the nature of the data (e.g., zero inflation, skewed frequency distributions) necessitates the use of non-Euclidean distance measures (Legendre and Legendre 2012). PCoAs were generated as in previous years, using two different distance measures to compute the similarity in arthropod communities between habitat types and sites: Bray-Curtis Dissimilarity (D14) and Hellinger Distance (D17). Both of these coefficients involve a transformation of each element of species-abundance data in a sample x species data table, called a general relativization. D14 involves a relativization of species-wise differences by the total abundance of species in two plots being compared. Thus, the abundance of each species is transformed to a proportion of the species total abundance. This makes the differences between abundant species contribute the same to D14 as differences between rare species. D17 performs best for linear ordination, such as PCA (Legendre and Legendre 1998) and involves transformation whereby each species observation is relativized by the total abundance of that species across all surveys, followed by a square root transformation (Legendre and Gallagher 2001); the application of the Euclidean distance measure to this Hellinger-transformed species abundance is known as Hellinger Distance (Legendre and Legendre 2012).

As the scale on the two PCoA axes was forced to be the same, the distance between sites in the ordination approximated their real distance. The results produced with the two association coefficients were compared to see if they produced the same spread of species assemblages. It is assumed that if dominant species are not strongly influencing the structure of assemblages among habitats, the two analyses would produce similar results.

PCA eigenanalyses were performed on arthropod species data using the Hellinger Distance measure to compare between habitat types and sites. Species correlations with treatments and sites were overlaid on the PCA ordination as species biplots, where the angles between descriptor axes describe the strength and direction of correlation.

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

Multivariate Regression Trees (MRT; De'ath 2002) reveal informative partitions in ecological community datasets for multiple taxa as response variables to a suite of environmental predictor variables (in our case: year, site, and habitat). MRT analyses were conducted to assess which variables were most important in shaping the arthropod assemblages. MRT analyses were performed using standardized abundances to account for uneven sampling, with the Hellinger distance measure in the MVPART package in R (De'ath 2014). The MVPART option 'pca=true' was used to generate the PCA ordinations that correspond to groups in the MRTs.

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

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

Taxa were considered indicators for a given habitat type when its indicator value (IndVal) was significantly different from random ($\alpha = 0.05$) after a Monte Carlo test based on 9999 permutations. IndVals range from zero (no indication) to 1 (perfect indication). We present all indicator taxa with significant IndVal greater than 0.25, following the suggestions of Dufrêne and Legendre (1997).

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

4.6.2 Songbirds

In 2015, analyses were constrained by a radius of 75 m from the point count centre (note: this distance often overlapped the paired treatment and controlled polygons, due to the small area of revegetation application; see maps in Appendix B). Data was also constrained by bird group, where Swallows, Swifts, and Hummingbirds were included as well as Songbirds, but other bird groups (e.g., Waterfowl) were excluded. Songbirds detected as fly-overs are also excluded from analyses, as these individuals may not be utilizing the habitat type containing the point count. Flyovers were not excluded for swallows, swifts, and hummingbirds as they are aerial foragers and almost exclusively detected as they fly overhead.

The following analyses were completed only for songbirds, and swifts, swallows, and hummingbirds to (1) provide an overview of the avifauna documented from each site and habitat sampled in 2015; (2) highlight differences in species richness, relative abundance, community similarity, and songbird assemblages in and adjacent to the drawdown zone of Arrow Lakes Reservoir; (3) compare data collected between 2009 and 2013 to those collected in 2015; and (4) continue to assess species of songbirds (i.e., swallows) that may be suitable focal species for monitoring the effectiveness of revegetation prescriptions applied in the drawdown zone of Arrow Lakes Reservoir.

Relative abundance, richness, diversity, and evenness analyses followed those described in Hawkes et al. (2014). Relative abundance was calculated as the number of individual songbirds, swifts, swallows, and hummingbirds recorded within 75 m of each per point count station, per survey (individuals per point count visit).

Corrected richness was calculated as the total number of songbird species detected per point count station, divided by the number of times each point count was visited. Shannon’s entropy index (H) and Pielou’s evenness (J) were also 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, 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.

Pielou's evenness quantifies how close (or even) in abundance each species is in a sample and is calculated as:

$$J = {}^{H}/_{H_{max}}$$

The more J tends towards 1, the more evenly the songbird species are distributed, and conversely, a value of J close to zero means that one or more species are dominating the community (i.e., the distribution is uneven).

Relative abundance, corrected species richness, diversity, and evenness were compared among years, habitat types, and sites with boxplots. Statistical tests were performed with two-way unbalanced crossed-factor ANOVA tests with 9999 permutations using Pierre Legendre's function 'anova.2way.unbalanced.R' (Legendre, 2015). This method computes ANOVA test statistics with distance-based redundancy analysis (RDA; Anderson and Legendre 1999; Legendre and Anderson 1999). Several significance tests were computed in series for comparisons among habitat types, among years, among sites and years (where data was subset for each habitat type or by site). Results of statistical tests were considered significant at α=0.05. P-values were not adjusted for multiple comparisons.

Species composition and assemblage similarity were assessed by Principal Coordinates Analysis (PCoA), and the computation of Kendall coefficient of concordance *W*, K-Means partitioning, and Principal Components Analysis (PCA; all computed in the vegan package in the R language, R Core Team 2016). These techniques were detailed in section 4.6.1.

Songbird food habits

Many songbird species feed on arthropods, and the relationship between arthropod biomass and songbird communities is relatively well-understood (e.g., Holmes et al. 1979; McMartin 2000). Revegetating the drawdown zone of mid- and lower Arrow Lakes Reservoir is predicted to first affect arthropod communities (as measured by changes in biomass, species richness, and composition; Section 5.2). These changes should be followed by a measureable change in either the songbird communities or the relative abundance of certain species depending on their feeding habits. For each bird species, a food group was assigned according to Campbell et al. (1990a,b; 1997; and 2001). Thus, we correlated availability of arthropods (biomass) to songbird species abundances in each site and habitat type using PCA ordinations. Overlays of the biomass of arthropods and bird species included the 2015 data only (songbird point counts and pitfall and Malaise trap data).

Nesting Evidence

A simple summary table is provided for all bird nests found in 2015, including their location, habitat type, and nest fate. Additional observations of breeding behaviour are also reported.

4.6.3 Terrestrial Mammals

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

4.6.4 Bats

Bat presence and activity was assessed by analysing triggered recordings from Wildlife Acoustics bat detector units using their proprietary automatic ID software, Kaleidoscope Pro v. 3.1.1. The software program has an integrated suite of bat data tools designed to quickly convert files, sort and categorize bat data by species, verify findings, visualize the data collected, and easily transform it into reports. Bat species richness was summarized for each sampling location and site type (i.e., control, treatment, and reference) and the relative level of activity (determined by the number of recordings attributed to a given species per detector hour) was assessed. Temporal activity (by hour and month) was also evaluated. 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.

5.0 RESULTS

5.1 Reservoir Conditions

The elevation of Arrow Lakes Reservoir ranged from a low of 433.49 m ASL during field session 2 to a high of 435.48 m ASL during field session 1 (Table 5-1). Arrow Lakes Reservoir reached a minimum of 423.83 m ASL on March 31, 2015 and maximum of 435.48 m ASL on June 13, 2015.

Table 5-1: Dates and reservoir elevations of each 2015 field session (FS). A = available; NA = not available

						Strata Elevation (m ASL)			
	2015		Reservoir Elevation (m ASL)			Lowest	Low	Medium	High
FS	Start Date	End Date	Min	Max	Mean	< 434	434–436	436–438	> 438
1	June 10	June 17	435.37	435.48	435.42	NA	NA	A	A
2	July 8	July 15	433.49	434.24	433.84	NA	NA	NA	A

Reservoir elevations in 2015 were lowest between February and March, hitting the lowest yearly point on March 31, 2015 (Figure 5-1). Water levels increased rapidly after that, peaking on June 13, 2015 then dropped steadily until year end. In 2015 the reservoir levels were lower than in previous years, reaching minimum and maximum elevations earlier, although overall the yearly pattern of reservoir elevation fluctuations has been consistent since 2008 (Figure 5-1).

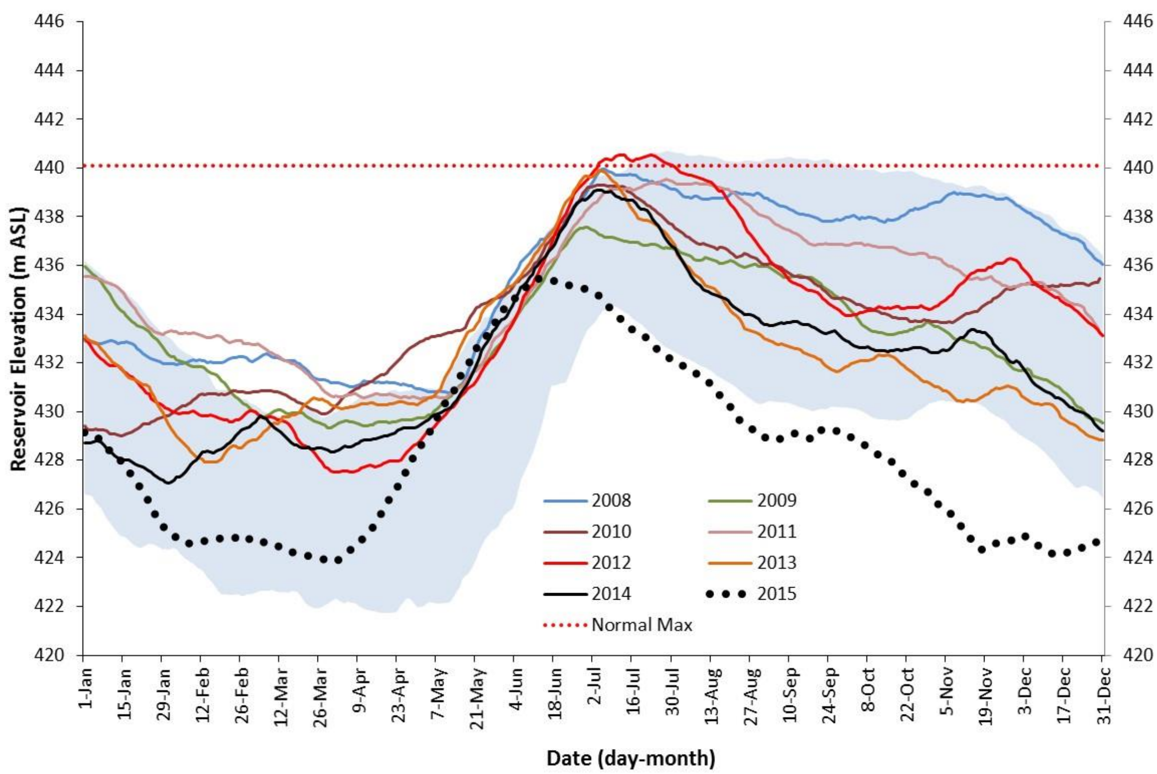


Figure 5-1: Arrow Lakes Reservoir elevations for 2008 to 2015. The 10th and 90th percentiles are shown for 1969-2015 (shaded area); m ASL= metres above sea level

5.2 Arthropods

A total of 228 taxa were documented from all sites and habitat types sampled in and adjacent to the drawdown zone of Arrow Lakes Reservoir in 2015. Specimens were collected from 22 orders, 136 families and 83 taxa were identified to genera or species.

5.2.1 Relative abundance and richness

Standardized arthropod abundance (number of individuals caught per 10 hour period) varied largely by trapping method with Malaise trapping yielding higher catch per unit effort (CPUE) than pitfall trapping (Figure 5-2). For Malaise traps, the treatment at Edgewood South and North were the only sites where treated areas had higher relative abundance than control or reference areas (Figure 5-2). For all other sites where revegetation prescriptions were applied (i.e. Burton Creek), regardless of trapping method the relative abundance of arthropods was higher in control areas than treatment areas. Similarly, the relative abundance of arthropods was higher in the drawdown zone than in the upland reference areas at all sites and trap types.

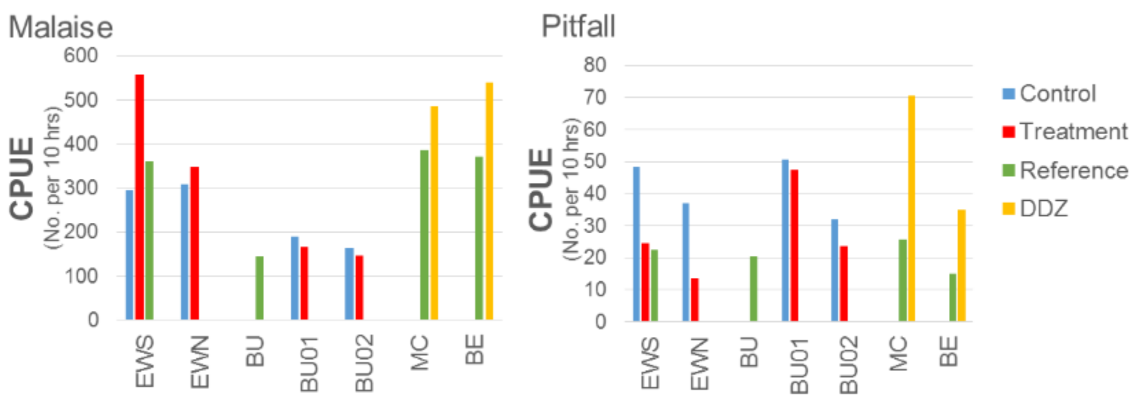


Figure 5-2: Abundance of arthropods (CPUE: catch per unit effort) assessed for Malaise traps (left) and pitfall traps (right) for each study site and habitat type sampled in 2015 in mid- and lower Arrow Lakes Reservoir. Sites are ordered from South to North of the reservoir. EWS: Edgewood South; EWN: Edgewood North; BU: Burton Creek (BU01: treatment 1; BU02: treatment 2); MC: Mosquito Creek; BE: Beaton Arm

Variation in corrected richness (richness per trap for each site and habitat type, corrected for trap effort) was higher in 2015 than 2013 (Figure 5-3). Richness varied significantly among sites and years (F=7.3, p=0.0001; F=175.4, p=0.0001) but not among habitat types (Table 5-2). Note: sampling occurred in different months between years (2013: May and June; 2015: June and July), which likely accounts for higher relative abundance in 2015.

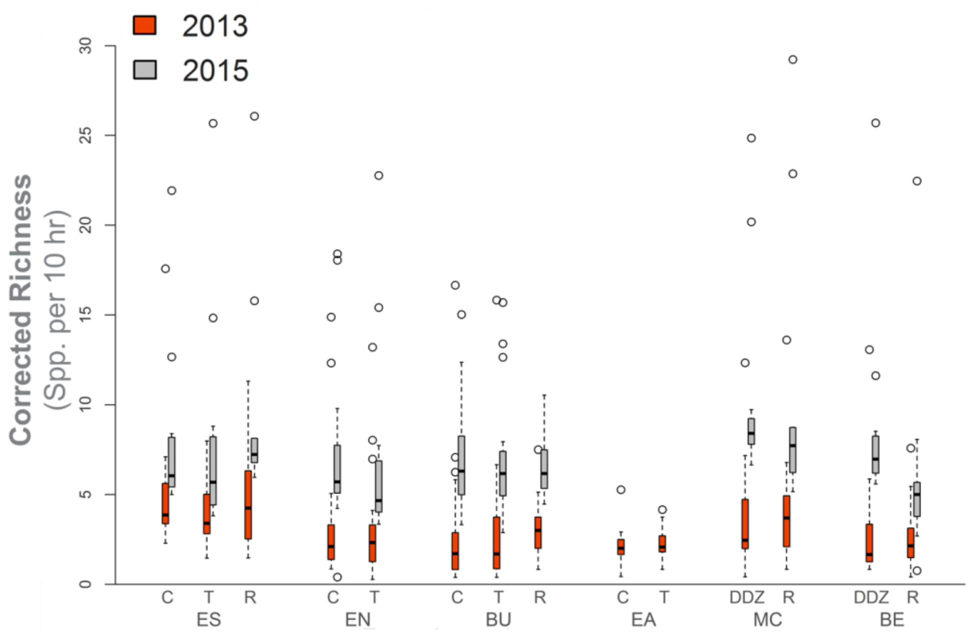


Figure 5-3: Corrected richness for each site and habitat type sampled in and adjacent to the drawdown zone of mid- and lower arrow Lakes Reservoir in 2013 and 2015. Sites ordered from south to north of the reservoir, EWS: Edgewood South; EWN: Edgewood North; BU: Burton Creek (pooled BU01 and BU02); EA: East Arrow not sampled in 2015; MC: Mosquito Creek; BE: Beaton Arm. Note: sampling occurred earlier in 2013 (May and June) than 2015 (June and July).

Table 5-2: Results of two-way permutational ANOVAs testing differences in corrected taxon richness by year, site, and habitat

Test	Factors	F	p-value
All Habitats	Year	175.4	0.0001
	Site	7.3	0.0001
	interactions	1.6	0.16
All Sites	Year	176	0.0001
	Habitat	2.15	0.098
	interactions	1.8	0.15
ES	Year	25.6	0.0001
	Habitat	0.6	0.58
	interactions	0.32	0.73
EN	Year	17.5	0.0002
	Habitat	0.14	0.71
	interactions	0.007	0.94
BU	Year	83.4	0.0001
	Habitat	0.04	0.96
	interactions	0.24	0.79
MC	Year	34.7	0.0001
	Habitat	0.01	0.915
	interactions	0.11	0.75
BE	Year	27.6	0.0001
	Habitat	3	0.085
	interactions	1.9	0.18

Forty-two species of spiders from fifteen families were identified in 2015 (vs. 49 species of 15 families in 2013, 71 species of 16 families in 2011 and 90 species of 18 families in 2010; Figure 5-4).

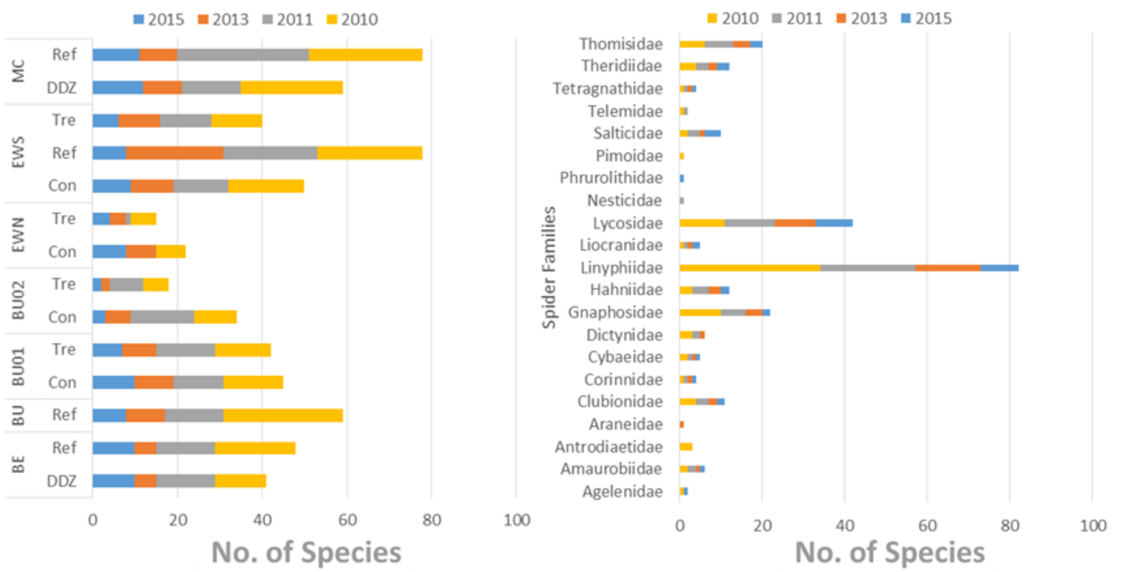


Figure 5-4: **Total number of spider species documented at sites in the mid- and lower Arrow Lakes Reservoir in each year from 2010, 2011, 2013, and 2015.** Data from all spider families are pooled in the left panel and data from all sites and habitats are pooled in the right panel. Note: data were not corrected for trapping effort, which differed substantially among years.

This trend seems to be due to the overall decline in abundance of individuals collected each year, which may be explained by the reduction in pitfall trap effort in recent years (4213 individuals; 2010 vs. 1610 individuals; 2015).

Spider species richness varied between site and habitat. The untreated study sites of Mosquito Creek and Beaton Arm had the highest richness among sites (MC DDZ = 12 species; MC reference = 11 species; BE DDZ = 10 species; BE reference = 10 species) while sites containing treated polygons had the lowest species richness (e.g., at Burton: BU02 control = 3 species; BU02 treatment = 2 species).

5.2.2 Taxa per site and habitat type

The numbers of arthropod taxa (order, family, or species) captured in Malaise traps and pitfall traps were used to characterize the arthropod taxa at each combination of site and habitat sampled in 2015 (Figure 5-5). As in 2013, pitfall traps captured more taxa[3] (*n*=143 taxa) than Malaise traps (*n*=128). Given that Malaise and pitfall traps target taxa with different life histories and diversity, this is not surprising.

[3] Identification effort varied between specimens caught in Malaise and pitfall traps. Taxonomic experts provided species-level identifications of spiders and grasshoppers, both of which were trapped primarily in pitfall traps. Because of this the number of taxa associated with the pitfall trap data is skewed upwards.

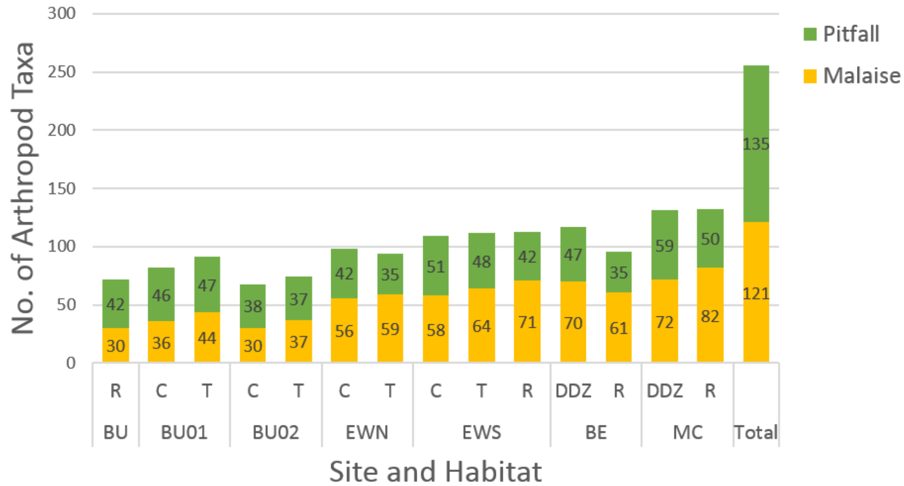


Figure 5-5: Total number (not standardized for effort) of arthropod taxa captured in Malaise and pitfall traps by site and habitat in the Arrow Lakes Reservoir (2015 data only). Taxa were constrained to species for Araneae and Orthoptera, family for Diptera, Hymenoptera, and Coleoptera, and Order for all other arthropods (excluded any records not meeting these classifications). DDZ: drawdown zone; R: reference; C: control; T: treatment. Sites are ordered from South to North of the reservoir; EWS: Edgewood South; EWN: Edgewood North; BU: Burton Creek (BU01: treatment 1; BU02: treatment 2); MC: Mosquito Creek; BE: Beaton Arm

5.2.3 Biomass

Arthropod biomass (dry weight, mg/hr) was compared by site and habitat type for pitfall and Malaise samples in 2015 (Figure 5-6). Overall, arthropod biomass was variable by site, habitat type, and trapping method. Average biomass of Malaise samples were similar for all sites, except at Edgewood south (EPL Black Cottonwood), where treatment Malaise biomass was greater than control on average. Pitfall trap biomass was lower for treatments than paired controls at Edgewood South, Edgewood North, and the Burton sedge plug treatment (BU02), but was greater for the live stake treatment at Burton (BU01) than the paired control area.

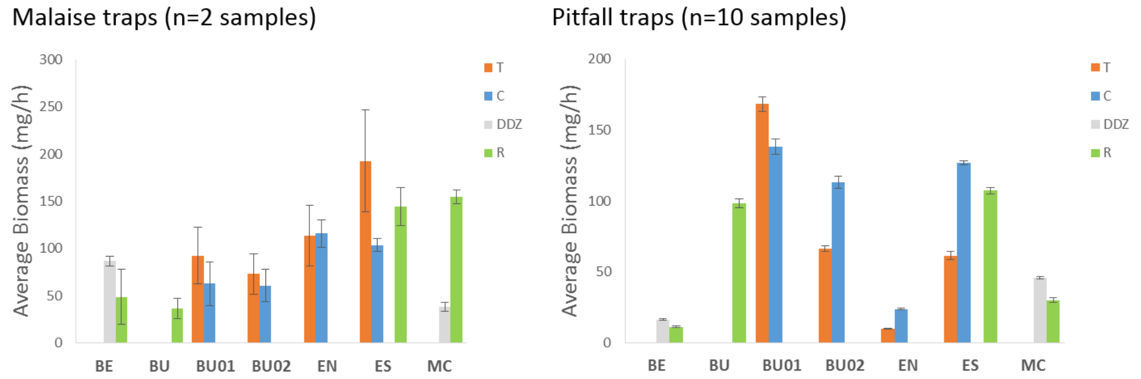


Figure 5-6: Average biomass (mg/h ± 90% CI) of Malaise samples (left) and pitfall samples (right) for each site and habitat type sampled in 2015. ES: Edgewood South; EN: Edgewood North; BU: Burton Creek (BU01: hand-planted live stake treatment; BU02: sedge plug seedling treatment); MC: Mosquito Creek; BE: Beaton Arm. T= revegetation treatment, C= control, DDZ= non-treated drawdown zone control, R= upland reference.

5.2.4 Arthropod assemblage composition and similarity

Consistent with the results of previous years, Arthropod assemblages did not form any specific patterns with respect to treatment and control areas in Malaise or pitfall trap samples (Figure 5-7 and Figure 5-8). Thus, we failed to detect an effect of revegetation on aerial or ground-dwelling arthropods. In general, the only notable pattern was for greater similarity among aerial arthropods of the reference sites and drawdown zone plots at Mosquito Creek and Beaton (Figure 5-7). However, this was not true for the composition of ground-dwelling arthropods, which showed high similarity between all drawdown zone, control, and treatment assemblages, which formed a distinct group apart from the reference arthropod assemblages (Figure 5-8).

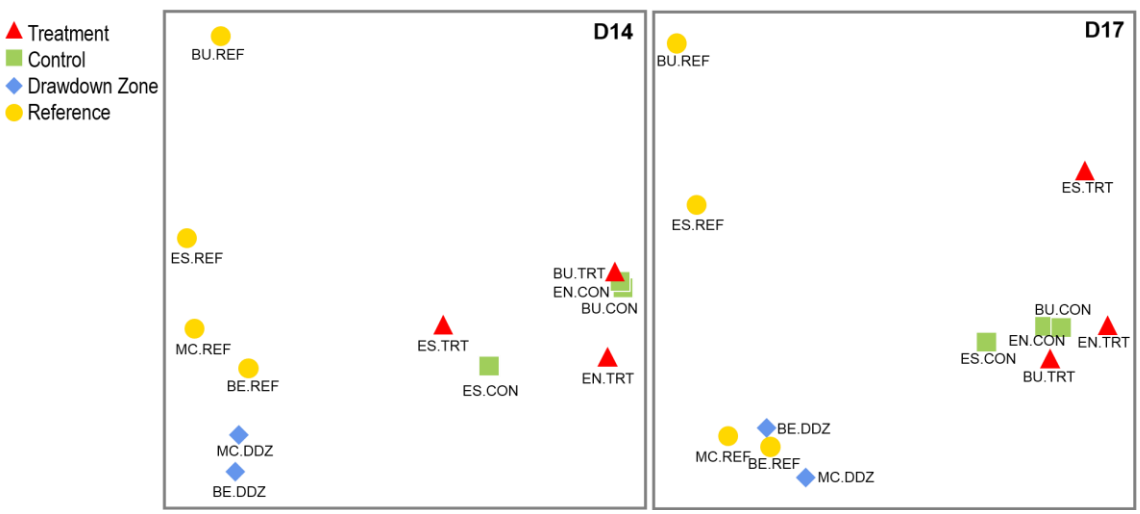


Figure 5-7: Principal Coordinates Analysis (PCoA) ordination of flying arthropod communities collected in Malaise traps, showing relationships among habitats and sites. Left: distances computed with the Bray-Curtis dissimilarity (D14) and Hellinger distance (D17)

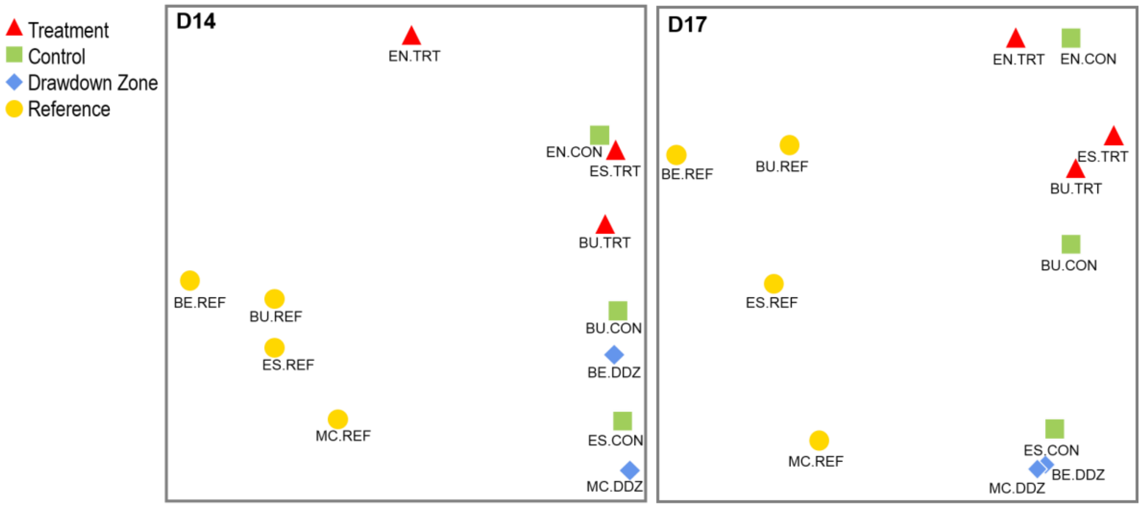


Figure 5-8: Principal Coordinates Analysis (PCoA) ordination of ground-dwelling arthropod communities collected in pitfall traps, showing relationships among habitats and sites. Left: distances computed with the Bray-Curtis dissimilarity (D14) and Hellinger distance (D17)

We failed to detect a difference in Coleoptera family assemblages between revegetation treatments and controls based on multivariate regression tree analysis for 2013 and 2015 data (MRT; Figure 5-9). Beetle assemblage composition was influenced most by year, habitat type, and site, where beetle assemblages of DDZ and reference sites formed a distinct branch apart from the control and treatment assemblages. Subsequent indicator analyses for groups at each terminal node in the MRT explain the families that are the dominant drivers of these assemblage patterns (Table 5-3). Beetle families in 2013, irrespective of site or habitat type, were dominated by Carabidae (ground beetles) and Elateridae (Click beetles).

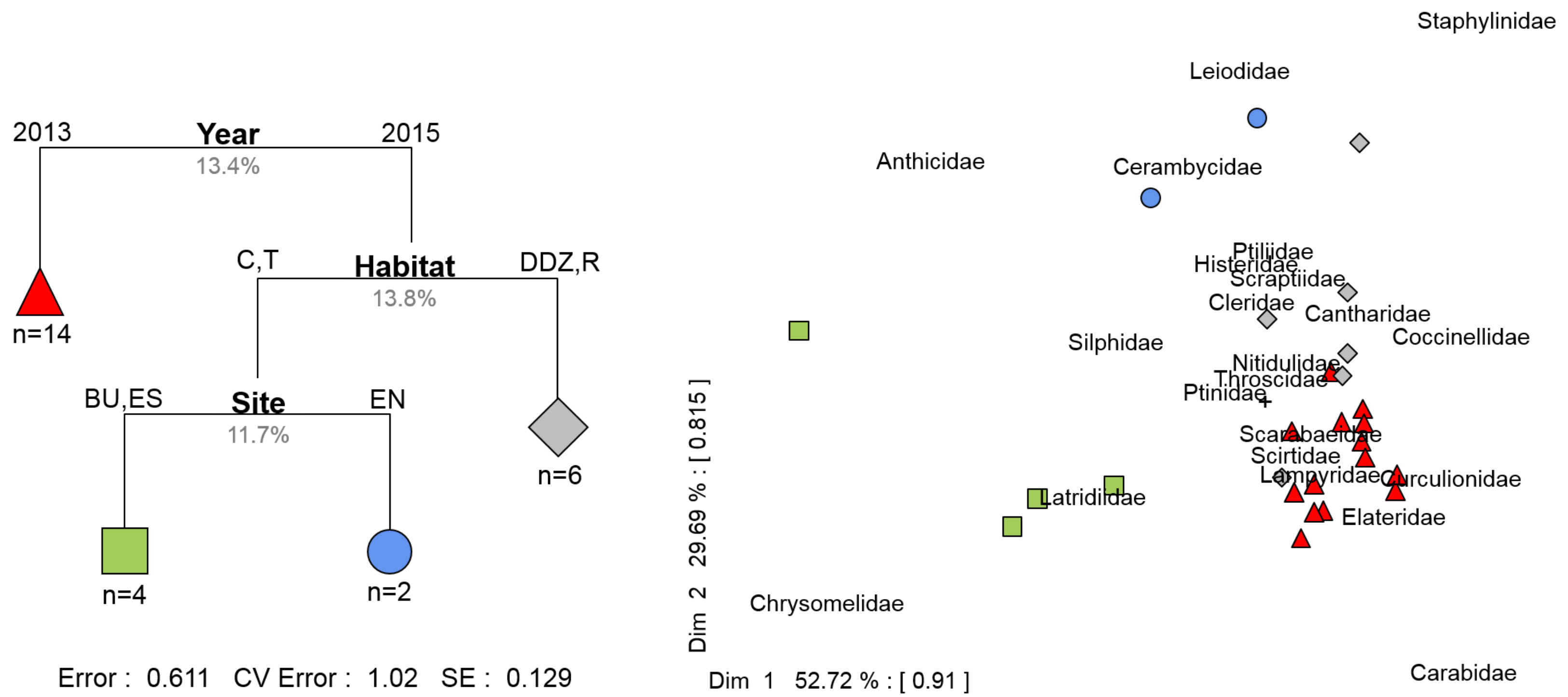


Figure 5-9: Multivariate regression tree (left, MRT) and corresponding Principal Components Analysis ordination (right, PCA) based on Hellinger distance depicting beetle family assemblages among sampling years (2013 and 2015 only), habitats, and sites. The tree was selected based on 500 cross-validations and explains 39% of the variance in beetle family assemblages. The most consistent and parsimonious tree is shown. Variance explained by each variable is given below each MRT node (grey text). Select taxa were plotted on the ordination for clarity. += ordination origin; C= control, T= revegetation treatment, DDZ= drawdown zone, R= reference; BU= Burton, ES= Edgewood South, EN= Edgewood North

Table 5-3: **Beetle families indicative of each group in the MRT analysis for 2013 and 2015 data.** Groups were assigned post-hoc, based on year, habitat type, and site combinations that were revealed in Figure 5-9. The results of Monte Carlo permutation tests show each indicator value (IndVal) that differed significantly from random (α = 0.05) after 9999 permutations. Symbols correspond to the MRT and PCA

Node	Group	Taxa	IndVal	p-value
1 ▲	**Year:** 2013	Carabidae	0.30	0.011
		Elateridae	0.48	0.040
2 ■	**Year:** 2015 **Habitat Type:** C and T **Site:** BU and ES	Chrysomelidae	0.69	0.004
		Latridiidae	0.45	0.045
3 ●	**Year:** 2015 **Habitat Type:** C and T **Site:** EN	Anthicidae	0.57	0.044
		Cerambycidae	0.63	0.022
		Staphylinidae	0.39	0.030
4 ◇	**Year:** 2015 **Habitat Type:** DDZ and R	Cantheridae	0.65	0.015
		Throscidae	0.50	0.040

Results of spider species assemblages were similar to previous years. Spider assemblages were influenced most by habitat type and site, forming two broad groups: one of drawdown zone, control, and treatments, and one of upland reference areas (Figure 5-10). Assemblages were also more similar between certain sites than others (Figure 5-10; Table 5-4).

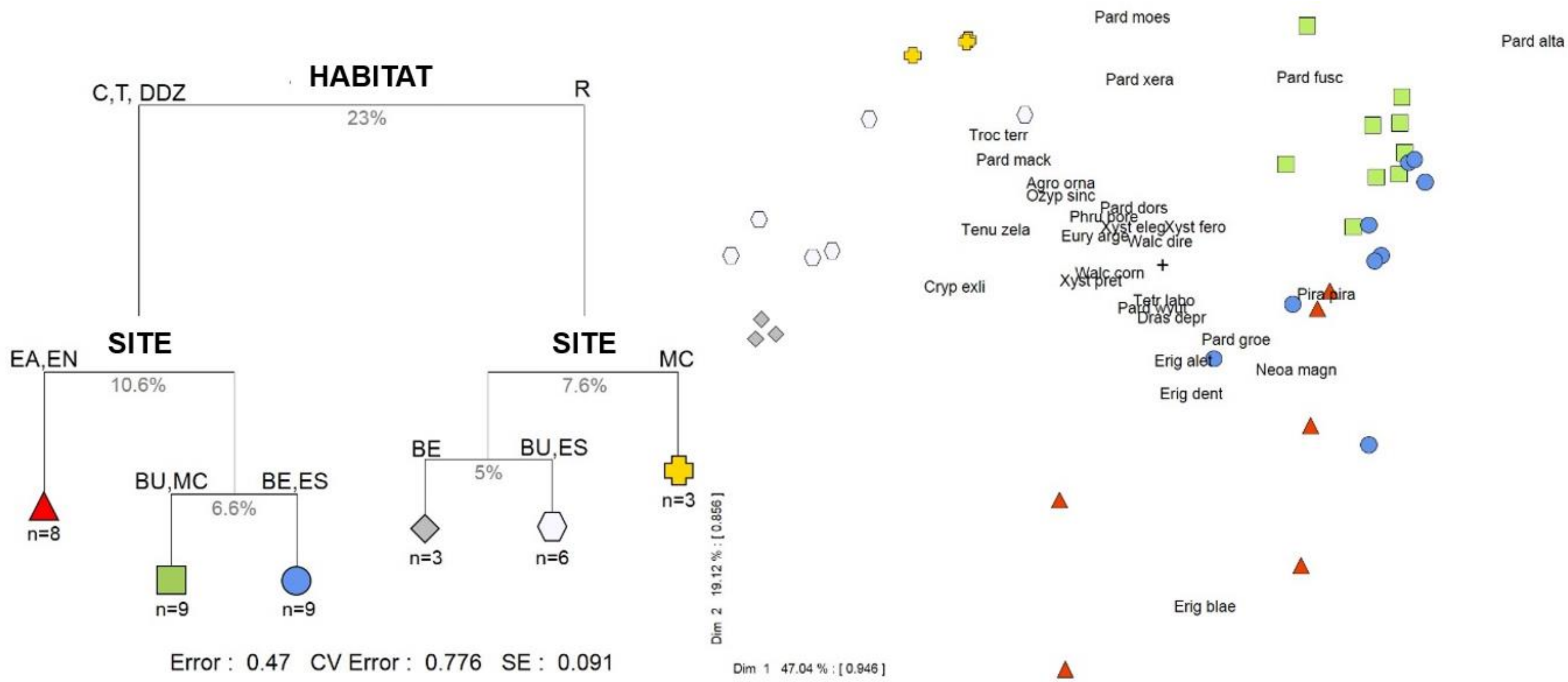


Figure 5-10: Multivariate regression tree (left, MRT) and corresponding Principal Components Analysis (right, PCA) ordination based on Hellinger distance depicting spider species assemblages among habitats and sites (for 2011, 2013, and 2015 data). The tree was selected based on 500 cross-validations and explains 53% of the variance in spider species composition. The most consistent and parsimonious tree is shown. Variance explained by each variable is given below each MRT node (grey text). Select taxa were plotted on the ordination for clarity. C= control, T= revegetation treatment, DDZ= drawdown zone, R= reference; BU= Burton, ES= Edgewood South, EN= Edgewood North, EA= East Arrow Park, BE= Beaton Arm, MC= Mosquito Creek

Table 5-4: Spider species indicative of each group in the MRT analysis for 2011, 2013, and 2015 data. Groups were assigned post-hoc, based on habitat type and site combinations that were revealed in Figure 5-10. The results of Monte Carlo permutation tests show each indicator value (IndVal) that differed significantly from random (α = 0.05) after 9999 permutations. Symbols correspond to the MRT and PCA

Node	Group	Indicator Species	IndVal	p-value
1 ▲	**Habitat Type:** C,T,DDZ **Site:** EA,EN	Erig blae	0.50	0.015
2 ■	**Habitat Type:** C,T,DDZ **Site:** BU,MC	Pard fusc	0.57	0.001
		Xyst fero	0.50	0.014
		Pard alta	0.42	0.001
		Oedo alas	0.39	0.046
3 ●	**Habitat Type:** C,T,DDZ **Site:** BE,ES	Neoa magn	0.69	0.001
		Pard groe	0.44	0.026
		Pira pira	0.37	0.033
4 ◆	**Habitat Type:** R **Site:** BE	Cryp exli	0.75	0.001
		Tenu zela	0.56	0.010
		Walc corn	0.56	0.018
		Xyst pret	0.54	0.012
5 ⬡	**Habitat Type:** R **Site:** BU,ES	Ozyp sinc	0.83	0.001
		Wald dire	0.50	0.027
		Agro orna	0.44	0.028
		Phru bore	0.39	0.047
		Eury arge	0.39	0.041
6 ✚	**Habitat Type:** R **Site:** MC	Pard xera	0.77	0.001
		Pard moes	0.65	0.001
		Xyst eleg	0.51	0.025
		Pard dors	0.51	0.019

Consistent with the results above, the overall test of concordance was significant (W = 0.064, F= 2.9, p < 0.001), with spider species partitioning into two groups according to K-means. The two groups were segregated along the X-axis of the PCA diagram (Figure 5-11) and were comprised of species associated with reference sites (W= 0.31 F= 8.2, p= 0.0001) and species associated with sites in the drawdown zone (whether treated or not; W= 0.16, F= 4.3, p= 0.0001). After correction for multiple testing, six species were significantly concordant in the drawdown zone group and twelve species were concordant with each other in the upland reference group (α= 0.1; Table 5-5).

The two groups of taxa suggest a drawdown zone or upland habitat association (Figure 5-11). Taxa in group 1 were associated with the control (drawdown sites included) and treatment sites in Arrow Lakes Reservoir. These drawdown zone taxa included three wolf spider species, one crab spider, and two sheet/web-building spiders that are ubiquitous across Canada.

Taxa in group 2 were associated with the upland (i.e., reference sites) of Burton Creek, Edgewood South, Beaton Arm, and Mosquito Creek. The groups associated with the 2015 data are similar to those delineated in the 2010, 2011, and 2013 data (Hawkes et al. 2011; Hawkes et al. 2014).

Focusing future analyses on those taxa in group 1 (the drawdown zone group) may help identify treatment effects associated with the application of the revegetation prescriptions. For example, if the live stake prescription increases the amount of treed habitat in the drawdown zone, then the taxa associated with that treatment should start to resemble that of the upland grouping shown in Figure 5-11.

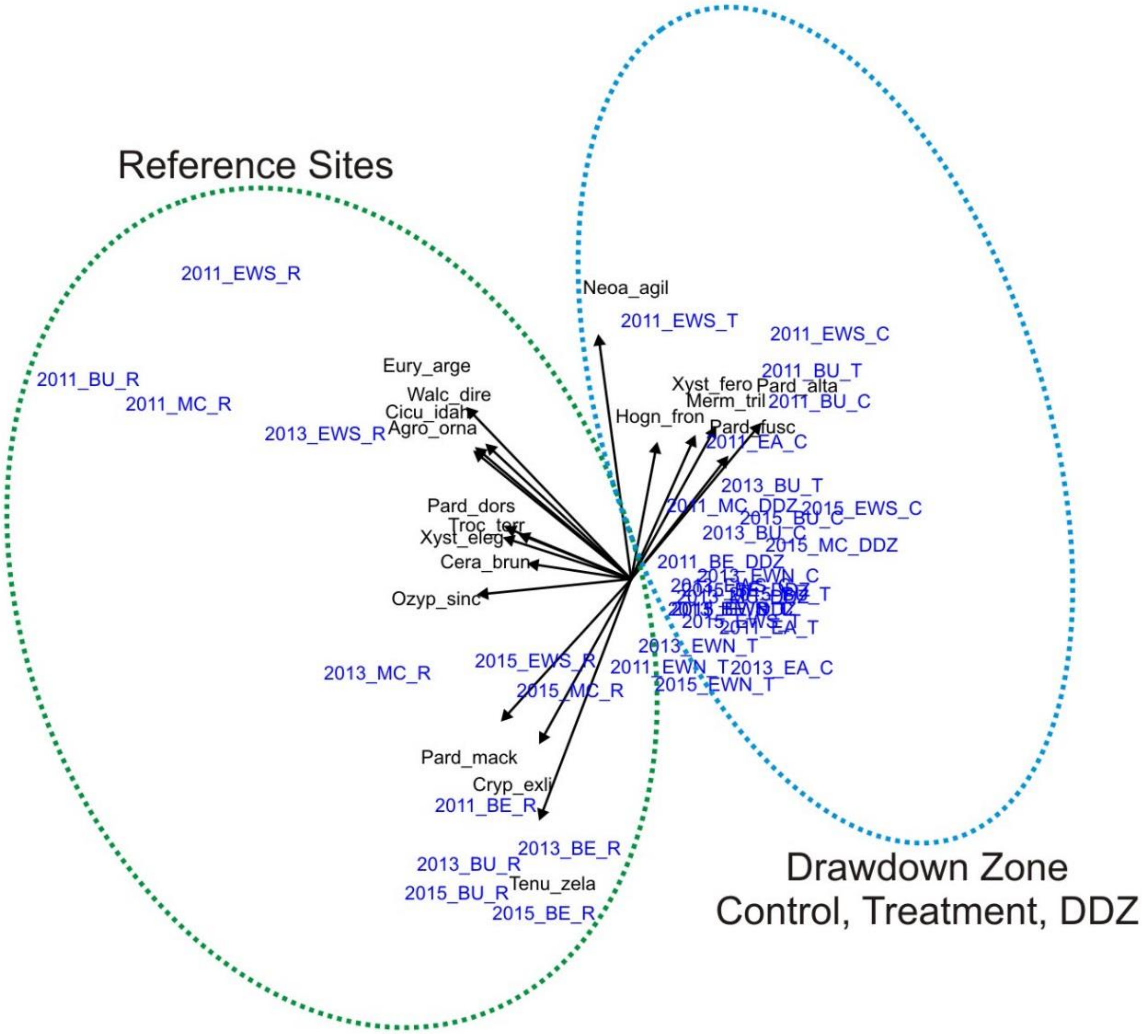


Figure 5-11: Principal Components Analysis ordination with superimposed results of the Kendall Concordance Analysis for 43 spider species and 39 'samples' (combination of Year x Site x Habitat). Groupings of arthropod taxa are shown by coloured ellipses (blue = DDZ, C, T; green = R). Black vectors represent spider species abundance (corrected for sampling effort). Both Malaise trap and pitfall trap data were pooled in this analysis. The horizontal axis explains 31 per cent of the variation in spider species assemblages. The vertical axis explains 15 per cent of the variation in spider species assemblages. BU= Burton, BE= Beaton, EA= East Arrow Park, EN= Edgewood North, ES= Edgewood South, and MC= Mosquito Creek. T= revegetation treatment, C= control, DDZ= untreated drawdown zone control, and R= upland reference

Table 5-5: Spider species concordant with groups resolved by Kendall Concordance Analysis. Only species occurring in more than two samples (site: habitat: year) were used in analyses (43 species, 39 sites). Species significant at α= 0.1 are shown

Group	Taxon code	Scientific Name	Family
1) Drawdown Zone, Treatment, and Control	Hogn_fron	*Hogna frondicola*	Wolf spiders (Lycosidae)
	Merm_tril	*Mermessus trilobatus*	Sheetweb and dwarf spiders (Linyphiidae)
	Neoa_agil	*Neoantistea agilis*	Dwarf sheet spiders (Hahniidae)
	Pard_alta	*Pardosa altamontis*	Wolf spiders (Lycosidae)
	Pard_fusc	*Pardosa fuscula*	Wolf spiders (Lycosidae)
	Xyst_fero	*Xysticus ferox*	Crab spiders (Thomisidae)
2) Upland Reference	Agro_orna	*Agroeca ornata*	Spiny-legged Sac Spiders (Liocranidae)
	Cera_brun	*Ceratinella brunnea*	Sheetweb and dwarf spiders (Linyphiidae)
	Cicu_idah	*Cicurina idahoana*	Mesh web weavers (Dictynidae)
	Cryp_exli	*Cryphoeca exlineae*	Dwarf sheet spiders (Hahniidae)
	Eury_arge	*Euryopis argentea*	Tangle-web spiders (Theridiidae)
	Ozyp_sinc	*Ozyptila sincera*	Crab spiders (Thomisidae)
	Pard_dors	*Pardosa dorsuncata*	Wolf spiders (Lycosidae)
	Pard_mack	*Pardosa mackenziana*	Wolf spiders (Lycosidae)
	Tenu_zela	*Tenuiphantes zelatus*	Sheetweb and dwarf spiders (Linyphiidae)
	Troc_terr	*Trochosa terricola*	Wolf spiders (Lycosidae)
	Walc_dire	*Walckenaeria directa*	Sheetweb and dwarf spiders (Linyphiidae)
	Xyst_eleg	*Xysticus elegans*	Crab spiders (Thomisidae)

5.3 Breeding Songbirds

A total of 1868 individuals from 1474 observations of 79 bird species were recorded in 2015 (Table 5-6). The lower number of species/observations relative to previous years is due to a combination of factors including the later period of sampling in 2015 which may exclude detections of certain species recorded only as migrants, the fewer point count stations due to the elimination of East Arrow Park as a study area, and the fewer point count visits (2 visits in 2015). Annual variation in songbird abundance may also be a factor. Despite the fewer overall species, the 2015 data give a good indication of the suite of breeding species within a site.

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

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

Songbirds are the focal taxa for this survey type, and were represented by 50 species in 2015 (Table 5-7). In addition, there were 3 species of swift and hummingbird detected. The remaining species were distributed among groups such as diurnal raptors, shorebirds and gulls, waterfowl, and woodpeckers. The number of songbird species documented per site varied from 37 at both Edgewood South and Mosquito Creek to 25 at Edgewood North. Excluding East Arrow, this is a consistent trend found in previous years, although the number of species is overall lower in 2015, as described above.

Table 5-7: Total number of species observed and detections per bird group recorded in and adjacent to the drawdown zone in 2015. BE: Beaton Arm; BU: Burton Creek; EN: Edgewood North; ES: Edgewood South; MC: Mosquito Creek. Spp: Species; Ind: Estimated number of individuals. Blanks indicate no observations

2015	BE		BU		EN		ES		LI		MC		Total	
Bird Group	Spp	Ind	Spp	Ind	Spp	Ind	Spp	Ind	Spp	Ind	Spp	Ind	Spp	Ind
Grebes					1	6							1	6
Hawks, Eagles, Falcons and Allies	1	2	3	7	1	2	1	9	3	5	2	10	4	35
Herons, Ibises and Allies	1	1											1	1
Kingfishers and Allies					1	1	1	1	1	3	1	1	1	6
Loons			1	1	1	7			1	1			1	9
Pigeons and Doves			1	2									1	2
Shorebirds, Gulls, Auks and Allies	1	5	2	28	3	22	2	16	2	26	2	18	5	115
Songbirds	33	235	31	338	25	191	37	214	28	161	37	288	50	1427
Swifts and Hummingbirds	2	6					1	3	2	2	1	1	3	12
Waterfowl	2	3	3	78	3	49			5	45	2	9	6	184
Woodpeckers and Allies	5	15	5	17	3	8	3	12	3	7	3	12	6	71
Total Species and Detections	**45**	**267**	**46**	**471**	**38**	**286**	**45**	**255**	**45**	**249**	**48**	**339**	**79**	**1868**

A total of 1,439 individuals of 33 species of songbirds, swifts, swallows, and hummingbirds were made in 2015. Restricting data to within 75 m of the point count centre resulted in 626 individuals of 47 species. Restricting data to within 30 m of the point count centre further reduced detections to 219 individuals of 37 species.

5.3.1 Relative abundance, richness, diversity, and evenness – 2015

The abundance of songbirds, swallows, swifts, and hummingbirds varied between 0 and 10 individuals per visit (i.e., each point count survey) within a 75 m radius of point count centres. Differences in relative abundance (number of individuals/visit) were significant among habitats (permutational ANOVA: F=12.1, p=0.0001), with reference plots having the highest relative abundance. Differences were also significant among sites (F=3.9, p=0.031). Interactions were not significant. These differences in relative abundance were not significant when only control and treatment were compared to each other (all p> 0.05), however, the interaction of site x habitat was significant (F=3.7, p=0.047). One-way permutational ANOVAs indicate that relative abundance was significantly lower for treatment point counts at Edgewood South, relative to controls (F=4.97, p=0.031), but not for Edgewood North or Burton Creek (p>0.05).

Corrected species richness (number of species per point count per visit) was higher in the reference areas compared to other habitats (Figure 5-12). This effect was significant (permutational ANOVA: F=14, p=0.0001), as was the difference in richness among sites (F=3.8, p=0.03). Interactions were not significant. No differences in species richness were found between control and treatment point counts (all p>0.05; only included Edgewood North, Edgewood South, and Burton Creek).

Differences in Shannon diversity (H) were not significant among sites (p> 0.05), but were among habitats (F=9, p=0.0007), with diversity highest in reference areas. Interactions were not significant. Differences in species diversity were not significant when only control and treatment counts were compared to each other (all p>0.05; included Edgewood North, Edgewood South, and Burton Creek).

Differences in species evenness (J) were not significant among sites or habitats (*p*>0.05), though variation in evenness was lowest in reference areas. Interactions were not significant.

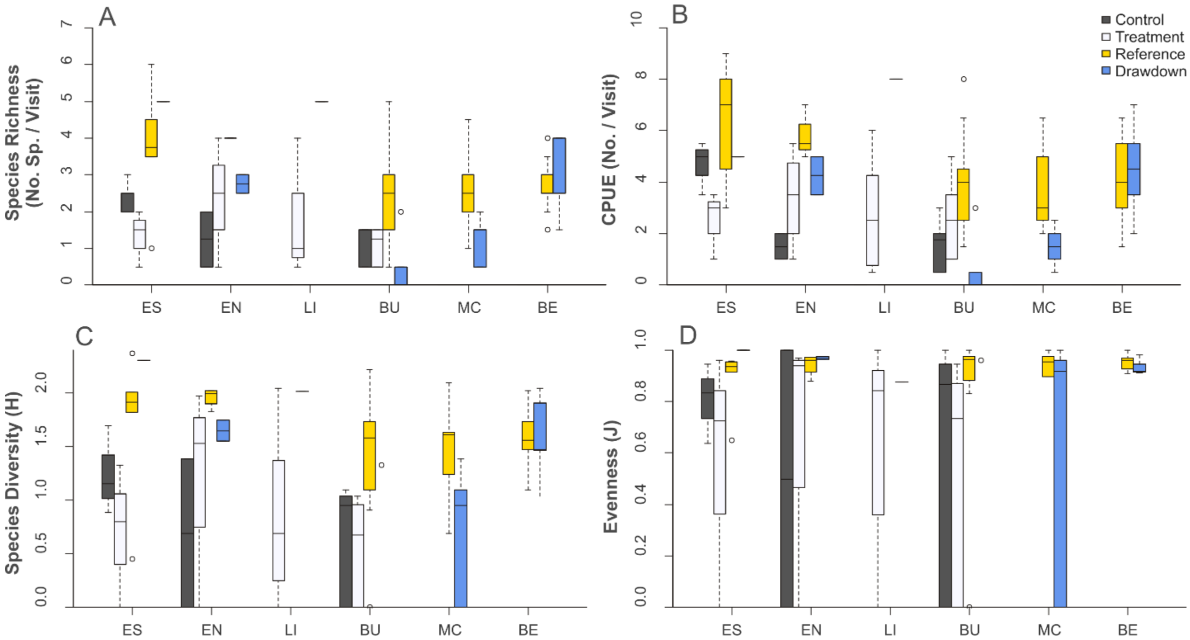


Figure 5-12: Variation in species richness (number of species per point count per visit; A), CPUE (number of individuals per point count per visit; B), diversity (C), and evenness (D) relative to habitat and site sampled in Arrow Lakes Reservoir in 2015. Sites are ordered south to north. Data constrained to 75 m radius from point count centres.

5.3.2 Relative abundance, richness, diversity, and evenness – all years

Differences in relative abundance (individuals per point count visit) were significant among habitat types (*F*=18.9, *p*=0.0001), but not among years (*p*>0.05). This could be due to outlying data points in 2010. Most incidences of high bird counts are associated with swallows or swifts, which are flocking and can amass in large numbers on occasion. When only control and treatment were compared, relative abundance was not found to be significantly different (*p*>0.05) by habitat type or year. Interactions were not significant.

Corrected species richness was significantly different among habitat types when all habitats were tested together (*F*=72.7, *p*=0.0001) and among years (*F*=5.5, *p*=0.0004; Figure 5-13). When only control and treatment were compared, differences were not significant (p> 0.05), but a year effect remained (*F*=2.5, *p*=0.042). Interactions were not significant for any of these comparisons.

Shannon Diversity (H) was found to be significantly different both among habitat types (*F*=108, *p*=0.0001) and years (*F*=8.35, *p*=0.0001). However, we failed to detect any significant differences (*p*>0.05) when only control and treatment were compared. A strong year effect was still present for comparisons between treatments and controls (*F*=3.6, *p*=0.008). Interactions were not significant.

Species evenness (J) showed a similar trend as diversity. Differences in evenness were significant among habitat types (*F*=30.8, *p*=0.0001) and among years (*F*=5.02, *p*=0.0008). Interactions were also significant (*F*=2.23, *p*=0.001). When only control and treatment were compared, differences were not found to be statistically significant ($p > 0.05$), but were significant among years ($F=2.6$, $p=0.0395$). Interactions were not significant in this analysis ($p > 0.05$).

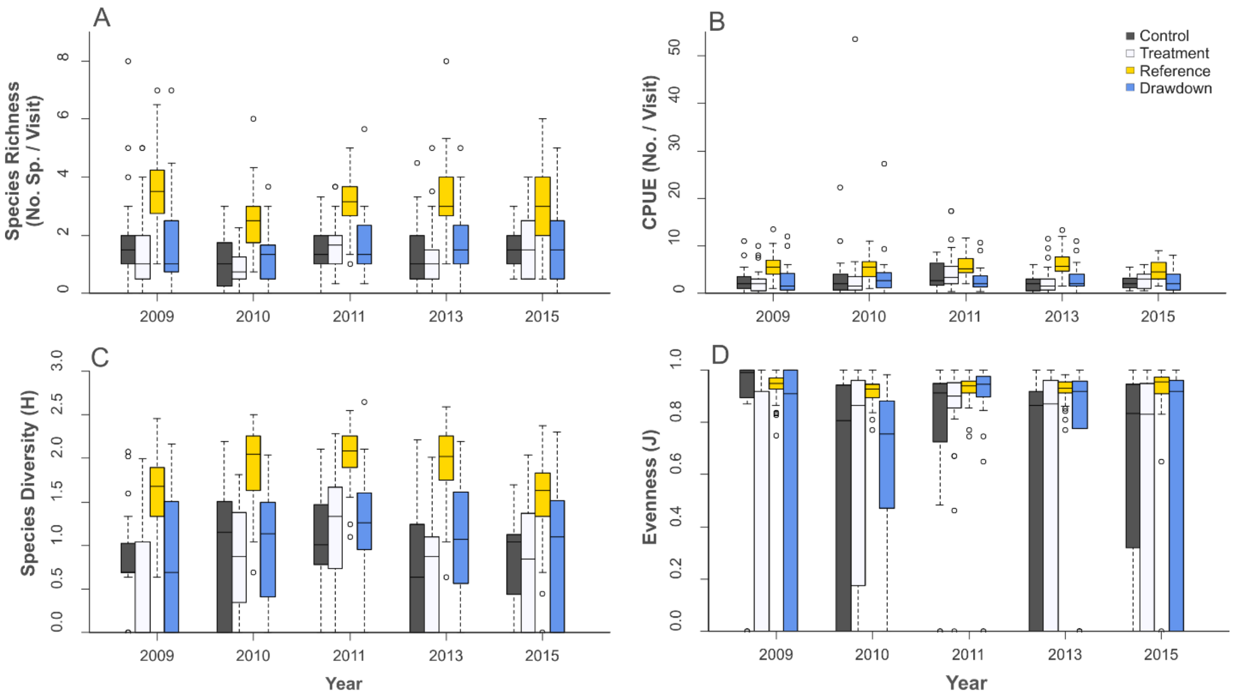


Figure 5-13: Variation in songbird species richness (number of species per point count per visit A), CPUE (number of individuals per point count per visit; B), diversity (C), and evenness (D) over time among treatment types in Arrow Lakes Reservoir. Data constrained to 75 m radius from point count centres.

5.3.3 Songbird species composition and similarity

Community similarity among sites and habitat types were assessed based on songbird species composition, using two different resemblance coefficients (D14 and D17; Figure 5-14). Both coefficients produced similar spatial patterns, which suggests that differences in species abundances did not drive overall compositional differences. The reference point counts from all sites grouped together, indicating that they shared more bird species than with the drawdown zone of the same site. The control, treatment, and drawdown areas in Edgewood South, Lower Inonoaklin, and Burton also grouped together, suggesting that these species assemblages are more similar than compared to the other sites (Figure 5-14, left). The treatment plot at Edgewood South was very similar to the control plot at Edgewood North under both coefficients, suggesting they share nearly the same species in common, with similar relative abundances.

In 2015, reference areas continued to group together as they did in previous years. Differences in songbird communities in other plot types show some differences among years, which could be due to natural variation in the songbird community or to a lack of influence of the treatments on songbird community similarity. More data are required to identify trends (if any) relative to community similarity.

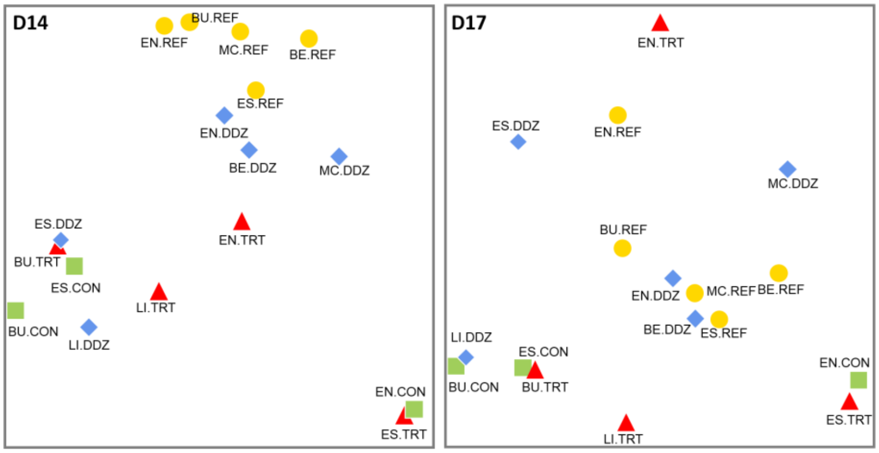


Figure 5-14: Principal Coordinate Analysis (PCoA) ordination diagram representing songbird community similarity for each site and habitat as computed by Bray-Curtis distance (D14; left) and Hellinger distance (D17; right). Colors refer to habitat type [green: control (CON), blue: drawdown zone (DDZ), red: treated (TRE), yellow: reference (REF). Two-letter prefix refers to site: BE = Beaton Arm; BU = Burton Creek; EN = Edgewood North; ES = Edgewood South; LI = Lower Inonoaklin; MC = Mosquito Creek

As in previous years, songbird species appear to mainly split in two groups according to K-Means partitioning and PCA: drawdown zone species, and upland species (Figure 5-15). Group 1 species consist of those associated with the reference zone in all sites, such as Red-breasted Nuthatch (RBNU), Pacific Wren (PAWR), MacGillivray's Warbler (MACW), and Swainson's Thrush (SWTH). Group 2 is composed of species found in the drawdown zone, both in control and treated sites, such as Savannah Sparrow (SAVS), Common Yellowthroat (COYE), and Willow Flycatcher (WIFL).

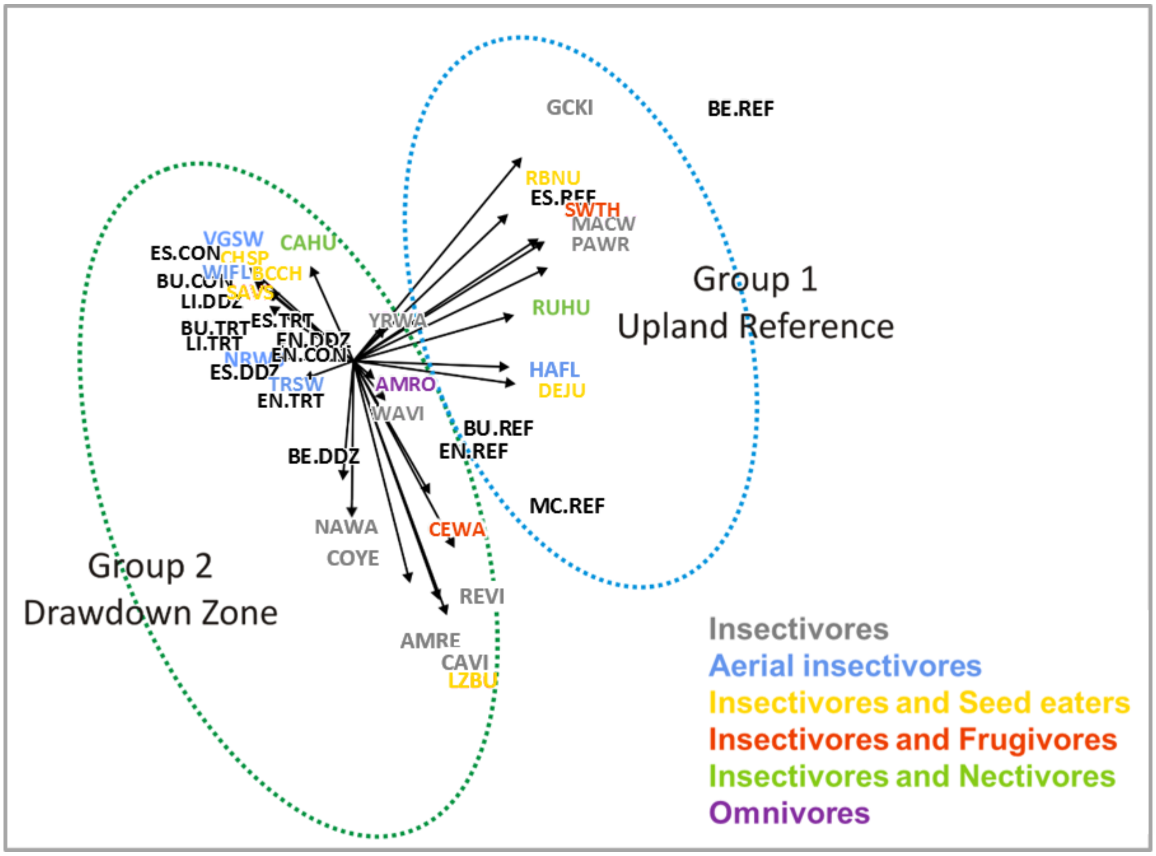


Figure 5-15: Principal Components Analysis ordination diagram with the K-Means partition results superimposed. Black vectors represent species. Site acronyms can be found in Figure 5-14. Groups as formed by K-Means and analysed by Kendall *W* are indicated by the coloured ellipses (blue for Group 1 and green for Group 2).

5.3.4 Songbird food habits

As in previous years, no apparent association between revegetation treatment and songbird food preference was found (i.e., birds that feed primarily on insects were not strongly correlated with treatment sites). However, the relative abundance of certain bird species was highest in the sites where treatments were applied (i.e., sites not including Beaton or Mosquito Creek). These species aligning with treatment sites were primarily insectivores, where arthropods comprise all or a substantial component of their diet.

Table 5-8: List of songbird species per food group[1] in 2015. Species in this table are the same as those depicted in Figure 5-15 and Figure 5-16

Food Group	Species Code
Insectivores	AMRE, CAVI, COYE, GCKI, MACW, NAWA, PAWR, REVI, TOWA, WAVI, YRWA
Aerial Insectivores	NRWS, TRSW, VGSW, VASW, WIFL,HAFL,
Insectivores and Seed eaters	BCCH, CBCH, CHSP, DEJU, LZBU, RBNU, SAVS, SOSP
Insectivores and Frugivores	CEWA, GRCA, SWTH, VATH
Insectivores and Nectarivores	CAHU, RUHU
Omnivores	AMRO, CORA

[1] Food groups were determined from Campbell et al. 1990a, b, 1997, and 2001.

The relative abundance of each songbird feeding guild was correlated with one or more orders of arthropods sampled in 2015 (Figure 5-16). For example, the relative abundance of Black-capped Chickadee (BCCH) and Violet-green Swallow (VGSW) was positively correlated with the biomass of caddisflies (Trichoptera), while the relative abundance of American Redstart (AMRE) was positively correlated with net-winged insects (Neuroptera), and American Robin was positively correlated with biomass of butterflies and moths (Lepidoptera).

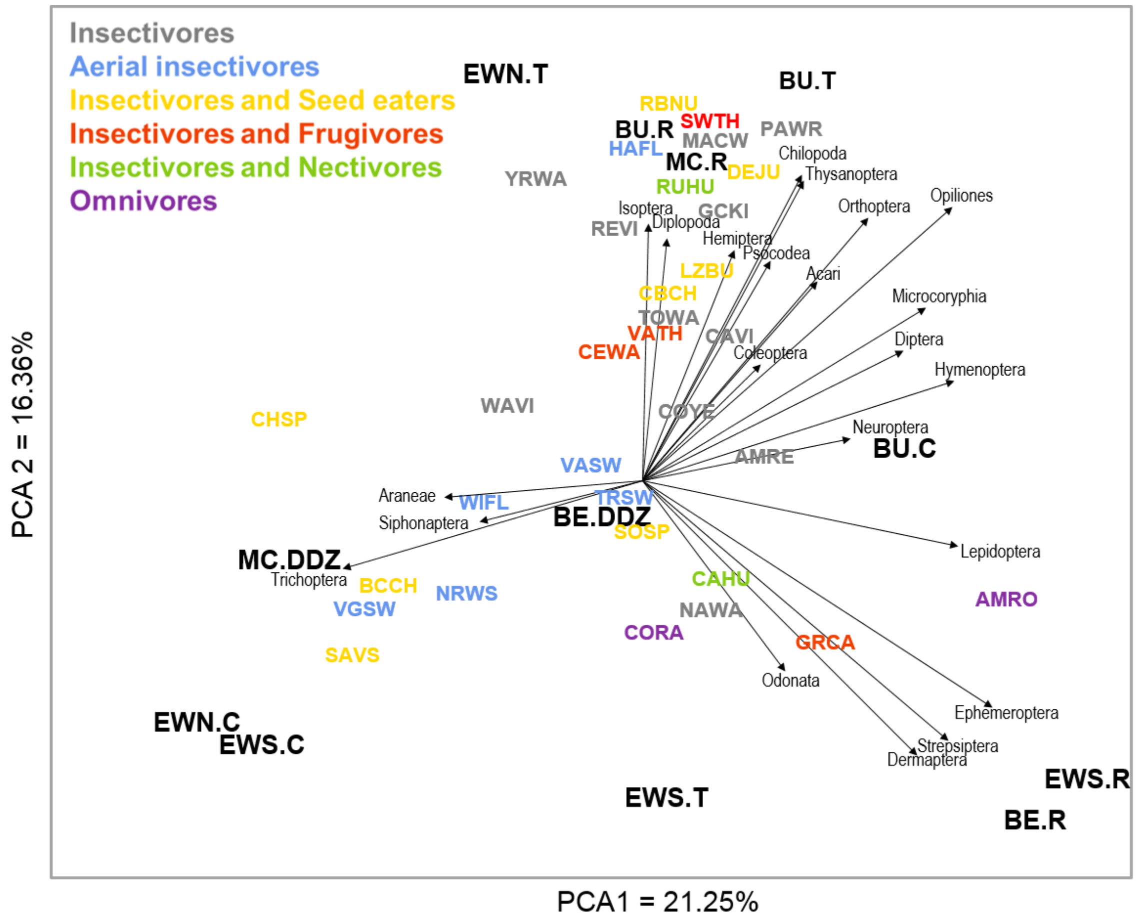


Figure 5-16: Principal Components Analysis (PCA) ordination of bird species (Hellinger distance) with superposition of arthropod orders. Axis 1 explains 21.25% of the variation in bird species assemblages. Axis 2 explains a further 16.36%. Black vectors are drawn to scale and direction with increasing biomass of each arthropod order. Four-letter bird species codes are provided for the centroids of each species on the ordination plot, colored according to food preference. T = treatment, C = control, DDZ = drawdown zone, R = reference; BU= Burton Creek, BE= Beaton, EWN= Edgewood North, EWS= Edgewood South, MC= Mosquito Creek

5.3.5 Nesting Evidence

In total, 14 nests of six species were located distributed across the surveyed sites (Table 5-9). Most sites had one to three nests, except Lower Inonoaklin which had seven, and Beaton which had none. Nests were distributed in all habitat types. While nest searching was not specifically focused on in upland habitats, three nests were located in reference areas. Four nests were located in control areas. The remaining nests were found in a variety of treatment types including excavator and hand-planted live stakes and sedge and grass plug seedlings. The majority of the nests in treated areas belonged to Spotted Sandpipers, which also accounted for 75 per cent of nests in control areas. Spotted Sandpiper is a commonly-occurring breeding bird throughout the drawdown zone of Arrow Lakes and Kinbasket reservoirs, but this sample size is too small to determine if Spotted Sandpipers display a preference for nesting in treated areas. The only other nesting shorebird was Killdeer, found in a mixed plug seedling treatment. The remaining nests were from shrub and tree-nesting species, although several of these were also found in treated areas, including one American Robin nest that was located in a planted cottonwood at Lower Inonoaklin. Nests ranged from an elevation of 427 m to 470 m. Shorebird nests ranged from 428 m to 441 m.

A total of five nests had unknown outcomes, due to eggs (n=4) or young (n=1) still in nest at the time of the last nest check of the season (Table 5-9). One nest was abandoned during nest building (American Robin), and another (Killdeer) was abandoned during incubation potentially due to human disturbances near the nest. The remaining six nests had success or probable/possible success at fledging at least one young. Two Spotted Sandpiper nests had one egg remaining after the remaining young had fledged, with a third nest having one egg left that might still have hatched as its siblings were still present indicating recent hatching. The Red-eyed Vireo nest suffered one confirmed chick mortality of unknown cause.

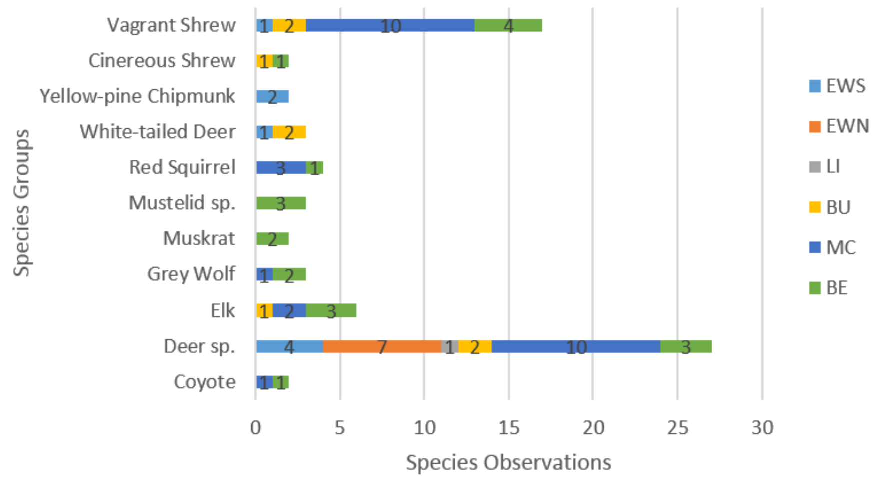
Table 5-9: Nest location and fate for all nests discovered during 2015 surveys. Site: BU= Burton Creek; ES= Edgewood South; LI= Lower Inonoaklin; MC= Mosquito Creek. Habitat type: DDZ= Drawdown zone (control/non-revegetated); UPL= Upland (reference or upland habitat above the drawdown zone); EPL= Excavator planted live stake; PS= Plug seedling (sedge or grass or mixed); HPL= Hand planted live stake

Nest	Species	Site	Habitat	No. Eggs	Substrate	Height (m)	Success/Fail
1	Spotted Sandpiper	BU	DDZ	4	Ground	0	Probable Success
2	Spotted Sandpiper	ES	DDZ	4	Ground	0	Possible Partial (1 egg failed)
3	Red-eyed Vireo	LI	UPL	3	Shrub (willow)	1.5	Probable Partial (1 dead nestling)
4	Chipping Sparrow	LI	DDZ	4	Shrub	0.5	Possible Success
5	Spotted Sandpiper	LI	EPL	4	Ground	0	Probable Partial (1 intact egg)
6	Killdeer	EN	PS	3	Ground	0	Failed (Abandoned)
7	Spotted Sandpiper	EN	DDZ	4	Ground	0	Success (possible partial)
8	Spotted Sandpiper	ES	EPL	4	Ground	0	Probable Success
9	Chipping Sparrow	MC	UPL	5	Conifer	0.75	Unknown (still incubating)
10	American Robin	ES	EPL	0	Conifer	2.5	Failed (Abandoned - no eggs laid)
11	American Robin	LI	EPL	4	Cottonwood	1.25	Unknown (still incubating)
12	Willow Flycatcher	LI	UPL	2	Shrub (rose)	1	Unknown (young still in nest)
13	Spotted Sandpiper	LI	PS	4	Ground	0	Unknown (still incubating)
14	Spotted Sandpiper	LI	HPL	4	Ground	0	Unknown (still incubating)

5.4 Terrestrial Mammals

Incidental observations were recorded between June 10 to 17 and from July 10 to 17, 2015. Mammal observations (visual sightings, wildlife signs) were documented by observers while performing other surveys. Although incidental observations do not include information about effort which limits analysis value, they are important, especially in long term studies to understand the distribution and habitat use of animals. The location of species observed, and mammal sign (e.g., bones, hair, and scat) in the drawdown zone and upland locations were recorded.

A total of 71 observations from 6 sites and 11 species groups were counted (Figure 5-17). The majority of species detected were ungulate species such as deer spp. [either White-tailed Deer (*Odocoileus virginianus*) and/or Mule Deer (*Odocoileus* *hemionus*)] followed by Elk (*Cervus canadensis*) sign Figure 5-17). The greatest number of observations was recorded at the reference sites of Beaton and Mosquito Creek and Red Squirrel, Mustelid sp., Muskrat, Grey Wolf, and Coyote sign were documented only at those sites as well. The most frequent sign recorded, after accidental shrew bycatch, were tracks followed by pellet groups (Figure 5-17). Cinereous Shrews (*Sorex cinereus*) were caught less frequently than Vagrant Shrews (*Sorex vagrans*) from pitfall traps.



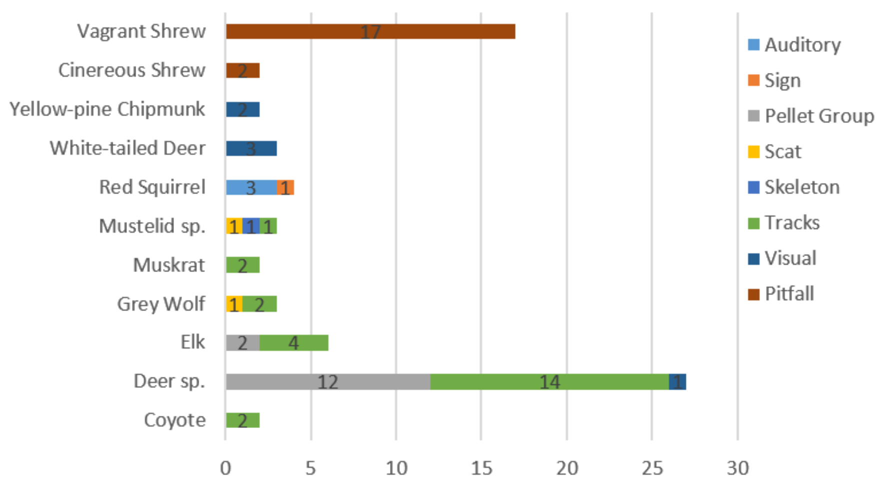


Figure 5-17: Total incidental mammal observations by site and observation type recorded in the Arrow Lakes Reservoir, 2015. Deer species were often pooled due to difficulty in differentiating these species by pellets/tracks. Sites: EWS = Edgewood South; EWN = Edgewood North; LI= Lower Inonoaklin; BU = Burton Creek; BE = Beaton Arm; MC = Mosquito Creek

5.5 Bats

From mid-June to early September, bat detectors (*n*= 8) sampled sites in Lower and Mid-Arrow Lakes for a combined total of 4,343.5 hours and recorded 43,918 bat calls. When run through Kaleidoscope Pro, 41,850 (95.3%) were assigned a species identification.

We detected all 12 bat species that were possible for the West Kootenays, including the Western Small-footed Myotis (MYCI), which was previously not confirmed in the region (Table 5-10). All but one site (Burton treatment) had at least one record of each species expected to occur in that particular reach.

Little Brown Myotis (MYLU) was the most frequently recorded species, and it had the most recordings at five sampling locations. At Lower Inonoaklin and Mosquito Creek, Silver-haired Bat (LANO) was the most commonly recorded species, and this was the most commonly recorded larger bat species during the 2015 sampling period. Fringed Myotis (MYTH) and Northern Myotis (MYSE) were the most infrequently detected species with only 18 detections each, followed by Townsend's Big-eared Bat (COTO) with 32 detections. Edgewood North was the busiest site in terms of detections, having more than three times the number of files assigned to species than any other site. Conversely, the bat detector at Burton Creek's treatment site had the fewest detections.

Table 5-10: Bat species documented at each site sampled in Lower and Mid-Arrow Lakes Reservoir in 2015. "N/A" indicates a species was omitted from analysis for the site based on low probability of occurrence. See Table 4-4 for species codes and corresponding common names

Site	Reach	Type	COTO	EPFU	LACI	LANO	MYCA	MYCI	MYEV	MYLU	MYSE	MYTH	MYVO	MYYU	# Species
BEDDZ	Beaton Arm	Control	7	27	278	44	900	N/A	106	1338	18	N/A	911	67	9
BUR	Burton Creek	Reference	3	43	13	173	1745	N/A	83	2102	N/A	N/A	987	71	9
BUT	Burton Creek	Treatment	0	15	3	32	315	N/A	6	937	N/A	N/A	196	103	8
ENT	Edgewood North	Treatment	1	354	2287	3237	2622	754	142	6354	N/A	7	1445	719	11
EST	Edgewood South	Treatment	2	102	58	959	360	68	53	1114	N/A	3	231	117	11
LIT	Lower Inonoaklin	Treatment	10	152	535	1609	451	53	67	1112	N/A	8	271	169	11
MCDDZ	Mosquito Creek	Control	2	99	695	1510	320	N/A	19	621	N/A	N/A	293	161	9
MCR	Mosquito Creek	Reference	7	57	447	586	416	N/A	46	351	N/A	N/A	248	23	9

The number of bat recordings per detector-hour (as a measure of relative abundance) was highest at Edgewood North, while the Burton Creek treatment site had the lowest rate (Figure 5-18). The overall average rate was ~9.46 bat recordings per hour. The detection rate for each species largely echoed the total number of recordings because recording effort was generally similar for each site, with the exception of the reference sites which both lost power prior to takedown in early September.

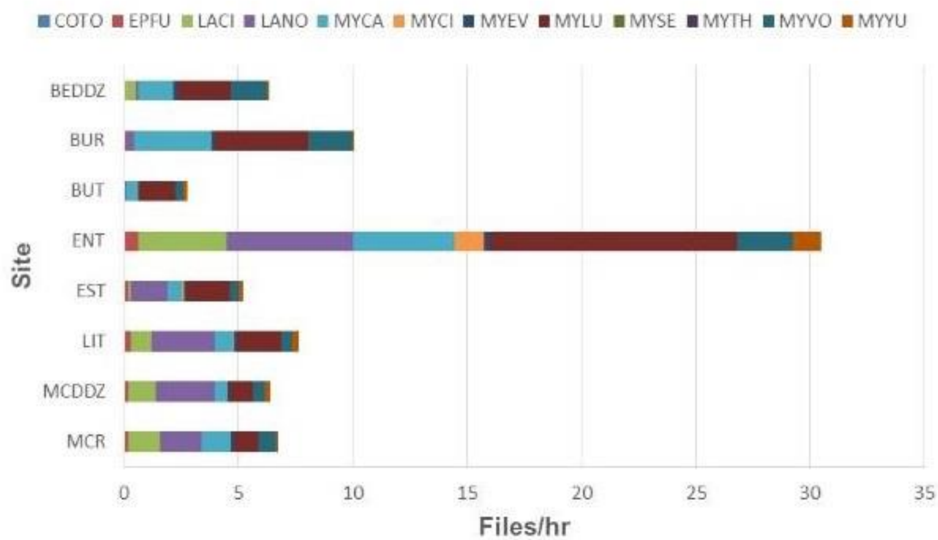


Figure 5-18: Relative abundance (recordings per detector hour) for all bat species at each site around the Lower and Mid-Arrow Lakes Reservoir, summer 2015

Data were pooled for each site type (i.e., treatment, control, and reference) and the proportion of detections for each species was compared (Figure 5-19). California Myotis (MYCA) had a stronger presence at reference sites, while Silver-haired Bat (LANO), Hoary Bat (LACI), and Yuma Myotis (MYYU) each made up a smaller proportion of detections compared to control and treatment sites. The proportion of Long-legged Myotis (MYVO) calls at the treatment sites was only 8% compared to the control and reference areas with 16 and 17%, respectively.

The control sites had the lowest proportion of Little Brown Bats (MYLU) and highest for Silver-haired Bats. Townsend's Long-eared Bat (COTO), Long-eared Myotis (MYEV), and Big Brown Bat (EPFU) were similarly distributed across all site types.

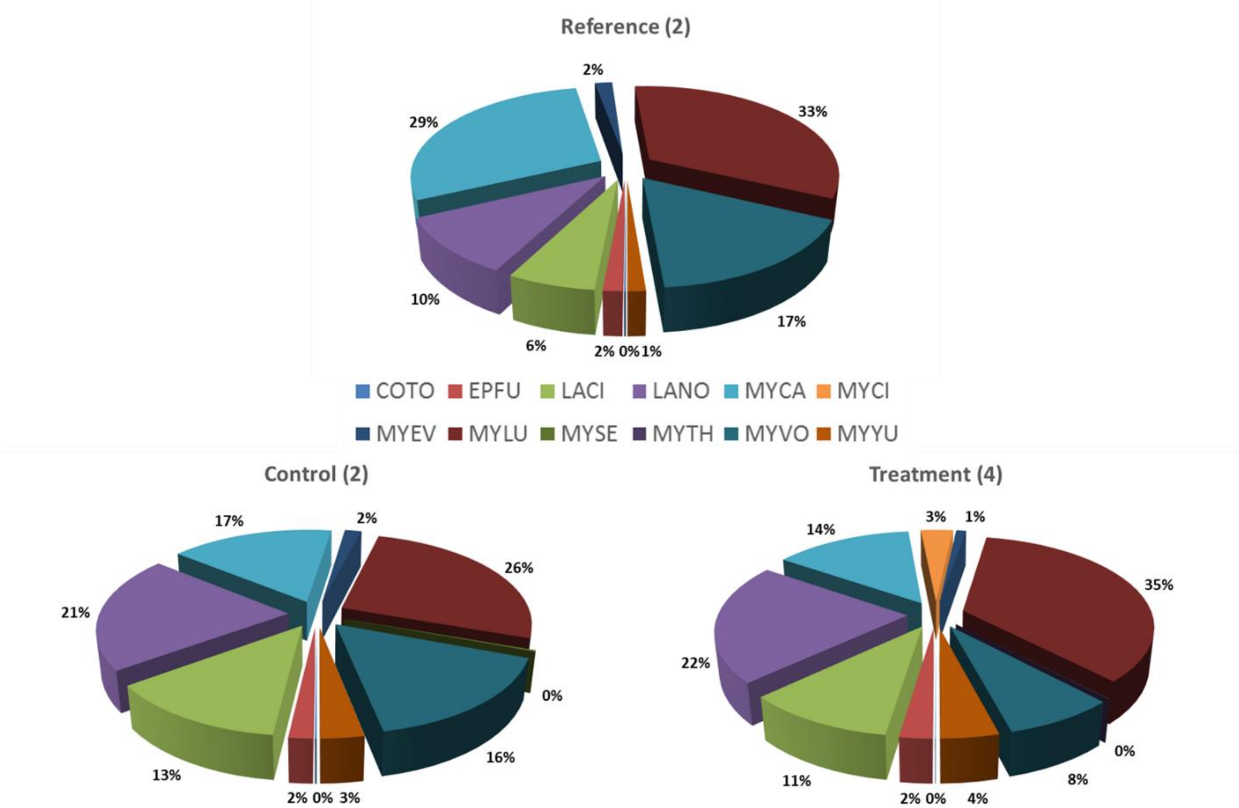


Figure 5-19: Proportion of files assigned to each of the 12 bat species documented from pooled site type locations around the Lower and Mid-Arrow Lakes Reservoir, summer 2015

Seasonal (monthly) activity patterns in 2015 indicate that bat activity is highest in June and August, with July showing a slight lull and September had a dramatic decline (Figure 5-20). The detectors were only operating until September 4 and the local weather conditions were poor in that period, which accounts for the apparent drop-off in activity during the short duration of September sampling. During the first three months of sampling, most bat species either had relatively consistent levels of activity with minor fluctuations (e.g., MYCA, MYLU, MYCI, and MYVO) or were most active during the first month and declined as the season progressed (e.g., LANO, EPFU, and MYEV). Yuma Myotis and Hoary Bat were the only two species whose activity levels increased during the first three months, and, curiously, the latter species was the only to actually experience an increase in September despite the local weather conditions. The seasonal activity patterns from 2013 show a more expected pattern, which involves a continual decrease in the number of detections per hour. Due to the exceptionally high number of detections from Beaton Arm in 2013, the relative abundance of bats was considerably higher. The bulk of the detections each month came from four *Myotis* species: MYCA, MYLU, MYVO, and MYYU. The most significant representation from a non-myotis species came from LANO in July, with ~5.6% of the total files per hour for the month.

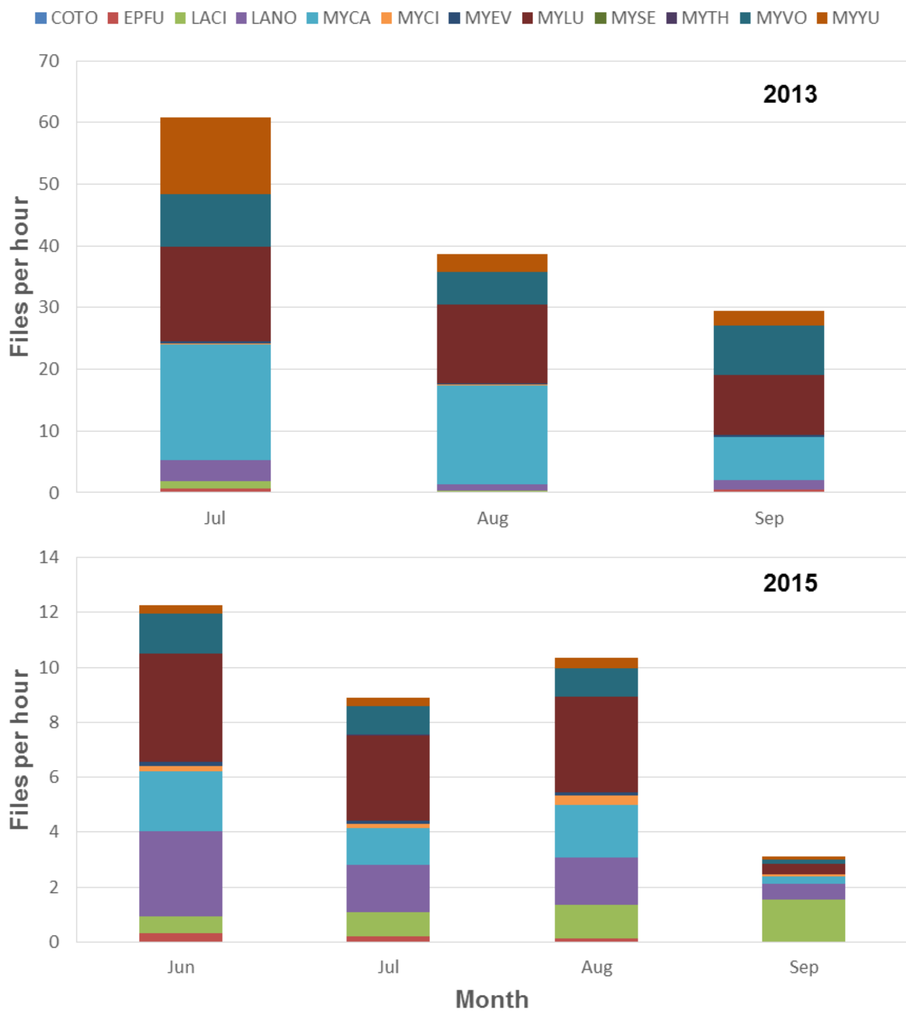


Figure 5-20: Seasonal activity levels for species of bats detected around the Lower and Mid-Arrow Lakes Reservoir in 2013 (top panel) and 2015 (bottom panel). Note varying values on y-axis

The total number of bat calls recorded during each hour was investigated to see when bats are most active (Figure 5-21). The 2015 sampling had a shifting schedule based on the date and latitude and longitude to determine the sunrise and sunset times, whereas the 2013 schedule was fixed around the approximate sunrise and sunset times when the bat detectors were deployed. Because sunrise and sunset times vary greatly across the sampling season, the 2015 schedule is an improvement. The 2013 data appears to show a normal distribution with peak activity occurring in the hour block starting at 2200 hours. Note, however, that the hour blocks 0100 to 0300 (along x-axis) are not included in the sampling schedule. In 2015, the adjusted schedule shows a bimodal, non-symmetrical distribution with an activity peak in the evening again in the hour block starting at 2200 hours and a smaller peak in the morning starting at 0400 hours. Most species were active throughout the night, with the exceptions being two low density species, COTO and MYTH, which were almost exclusively recorded during the evening period. A single COTO call from the morning period (0500 hour block) in 2013 was the only record that was contrary. The bat detector results in 2015 did not show any dramatic differences in species relative abundance by hour, with all species having the most number of recordings during the three most active hour blocks (2100, 2200, and 2300 hours). The 2013 results had a couple interesting trends: (1) MYYU was primarily active during the 2300 and 0000 hour blocks, and (2) MYVO had increased activity earlier in the evening (2000 and 2100 hour blocks) and again in the morning (0400 hour block).

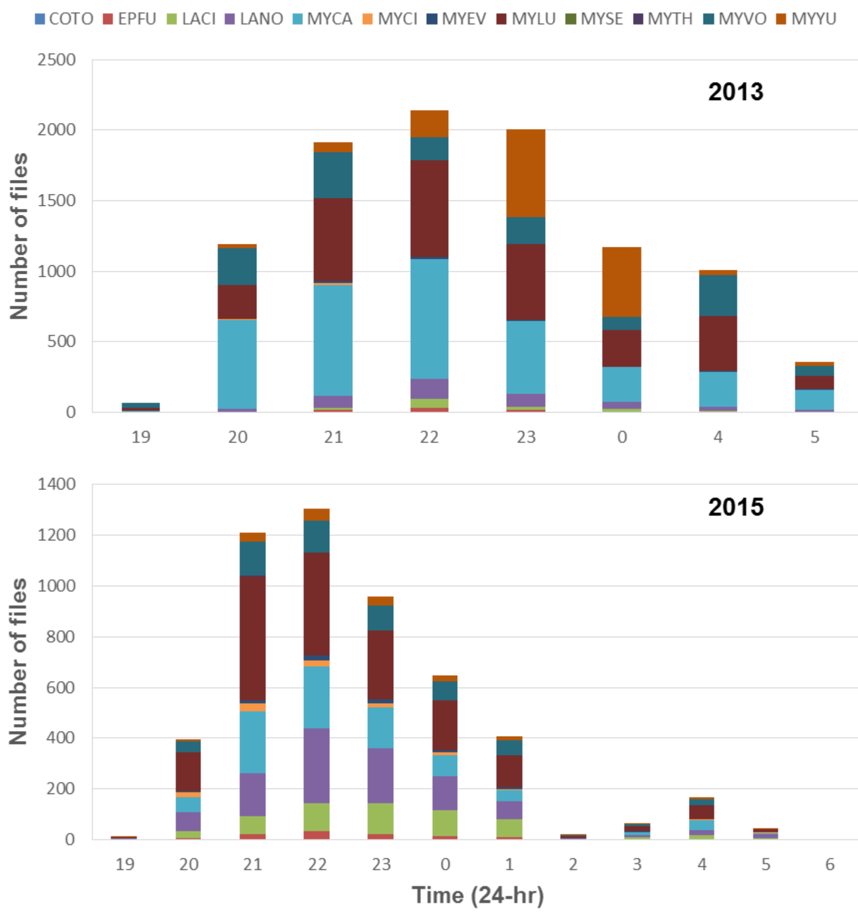


Figure 5-21: Hourly activity levels (number of files) for all species of bats detected around the Lower and Mid-Arrow Lakes in 2013 (top panel) and 2015 (bottom panel). Note: varying values on y-axis and discontinuous hourly scale on the x-axis for 2013. Data corrected for the number of bat detectors deployed each year

The number of detections from bat detectors set out in 2013 (n=3) were plotted by date along with 2015 (n=8) data to compare activity levels of each species (Figure 5-22). Despite the disparity in number of detectors between the two years, the frequency of California, Long-legged, and Yuma Myotis detections was considerably higher in 2013, due largely in part to high levels of activity at the Beaton Arm control site in the drawdown zone which accounted for 78.8% of the detections that year. Northern Myotis (MYSE) was recorded into early September in 2013, whereas the latest record in 2015 was in the first half of August. In 2015, the middle beaver pond drained following a dam failure. Further data collection is needed to determine whether the high bat activity levels recorded in Beaton Arm in 2013 was the result of a healthy stepped beaver pond system, annual variation, or natural cycles (e.g., a large hatch of aerial insects). The bimodal appearance of the 2013 data is the result of bat detectors losing battery power (as opposed to solar in 2015), and does not reflect a complete drop-off in activity from early to mid-August.

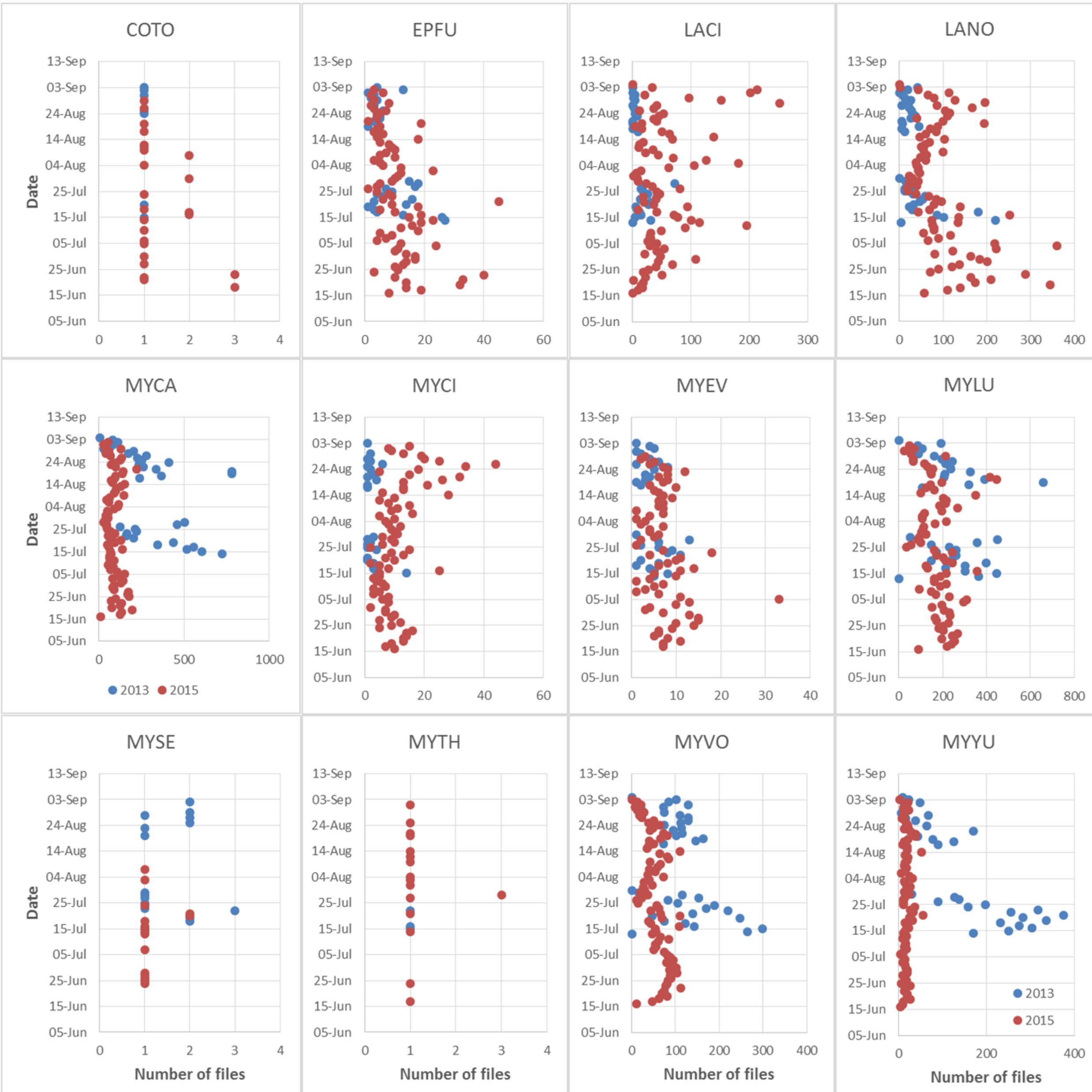


Figure 5-22: Monthly activity levels (number of files) for each species documented at the Lower and Mid-Arrow Lakes in 2013 (*n* = 3) and 2015 (*n* = 8). Note varying values on x-axis. See Table 4-3 for species codes and corresponding common names.

5.6 Amphibians and Reptiles

Amphibian and reptile data is collected incidentally with CLBMON-11B1 and under CLBMON-37 (Hawkes and Tuttle 2013; Hawkes et al. 2015) in Arrow Lakes

Reservoir. We have recorded five species of amphibians from the drawdown zone of Arrow Lakes Reservoir: Western Toad (*Anaxyrus boreas*), Columbia Spotted Frog (*Rana luteiventris*), Pacific Chorus Frog (*Pseudacris regilla*), and Long-toed Salamander (*Ambystoma macrodactylum*). Additionally, six reptiles are also known to use the drawdown zone, including: Western Painted Turtle (*Chrysemys picta bellii*), Western Terrestrial Garter Snake (*Thamnophis elegans*), Common Garter Snake (*Thamnophis sirtalis*), Rubber Boa (*Charina bottae*), Northern Alligator Lizard (*Elgaria coerulea principis*) and Western Skink (*Plestiodon skiltonianus*).

6.0 DISCUSSION

CLBMON-11B1, initiated in 2009, is a long-term wildlife monitoring project that aims to assess the efficacy of revegetation prescriptions in enhancing the suitability of habitats in the drawdown zone for wildlife, and to develop a minimum of three wildlife enhancement prescriptions that can be implemented in the drawdown zone to further improve habitat suitability. The original focal species groups selected for this study were songbirds, arthropods, and mammals (ungulates). In addition to studying these groups, bats were incorporated into the 2010 sampling program because of the known relationships between bats, wetland and riparian habitat, and arthropods, which are their primary food source. In 2013, formal sampling (i.e. pellet plots and aerial surveys) for ungulates were removed from the study design based on unsuitable revegetation prescription size for measuring ungulate use and recommendations by Hawkes et al. (2012), and supported by Adama and Hawkes (2015).

The revegetation prescriptions applied in the drawdown zone are likely to affect prey populations (terrestrial arthropods) before they affect the predators of those arthropods (songbirds and bats). The direction and magnitude of those changes in arthropod populations will be tracked over time and will serve as a metric to assess the efficacy of each revegetation prescription applied in the drawdown zone.

In general there does not appear to be a strong relationship between the relative abundance of arthropods, songbirds, and revegetation prescriptions applied in the drawdown zone. Although, some site-specific trends are emerging, the treatment at Edgewood South and North were the only areas that had higher relative abundance of arthropods than control or reference areas. This trend was found only for Malaise trap samples (n=1 per habitat) and not for pitfall trap samples (n=5 per habitat). For Burton Creek, regardless of trapping method the relative abundance of arthropods were higher in control areas than treatment areas.

The relationship between revegetation prescriptions and the relative abundance, richness, diversity, and evenness of songbirds is variable by site for 2015 data alone (Figure 5-12). While some sites have higher values in treatment areas than controls, the opposite is true at other sites. This is likely the effect of site specific differences in topography, adjacent habitats, and the success of revegetation prescriptions at the various sites. Examining data across all years of study (2009 – 2015), a significant effect of habitat type was found for richness, abundance, diversity, and evenness. However, this was due to the greater value for these metrics in the reference point counts, while the drawdown zone, treatment, and control values largely overlapped (Figure 5-13). Reference plots are forested, have greater structural complexity and niche-space, and were expected to host a greater number of species and individuals than plots within the drawdown zone. Indeed, when comparing the control and treatment plots directly, to better assess possible revegetation prescription effects, no significant differences were found. While there may be some site specific differences, overall these metrics of songbird utilization do not differ, suggesting that over the study period as whole, these metrics do not greatly differ between control and treatment plots. In contrast, a year effect remains for virtually all these metrics, regardless of the inclusion of reference plots.

Consistent with previous years (see Hawkes et al. 2011a, 2012, 2014), terrestrial arthropod and songbird assemblages both partitioned between the drawdown zone and adjacent upland habitats. No distinct assemblages were found between control and treatment areas within the drawdown zone suggesting no obvious treatment effect. Although, site specific differences in topography, proximity to adjacent habitat, fluctuating reservoir levels, annual natural variation and differences in revegetation success at some sites could obscure trends. More time and site-specific information is required to assess how species richness, biomass, and relative abundance change as a result of the implementation of the revegetation prescriptions.

This was the first season of dedicated nest-searching effort from the drawdown zone of Arrow Lakes Reservoir as part of this project. Nest data helps determine not only what species are present and their abundance (as gathered by point count data), but also if drawdown zones, specifically treated areas, provide suitable nesting habitat for birds, and if so, what species. Results from this year’s nest searching efforts indicate that treated areas had more nests than control areas (seven versus four), and that those in treated areas were found in a variety of revegetation prescriptions (Table 5-9). Furthermore, eight of the eleven nests found in the drawdown zone belong to shorebirds, a group not easily surveyed by point count methods but likely to be consistently present in the region across years. The presence of the American Robin nest in a planted cottonwood is evidence that birds are utilizing transplanted vegetation for nesting, though it is not known how regular of an occurrence this may be. Further years of nest monitoring are needed to assess whether patterns hold.

Acoustic monitoring of bats in the drawdown zone has resulted in the documentation of 12 bat species in mid- and lower Arrow Lakes Reservoir. The data is not correlated with a specific treatment but provides an overview of the distribution and occurrence of bat species using the drawdown zone of the reservoir. The ability to correlate the presence of bats to arthropod biomass is confounded by the fact that data collected from passive acoustic monitoring may not be correlated to bat abundance. Using the number of detections per hour is only a proxy for bat activity, which may not be correlated with food availability.

The effectiveness monitoring program developed and implemented in mid- and lower-Arrow Lakes Reservoir should continue, but some changes are recommended. These methods should also be appropriate for monitoring the efficacy of proposed wildlife physical works promoted in Hawkes and Howard (2012). Recommendations regarding these refinements are provided in Section 6.3.

6.1 Management Questions and Hypotheses

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

Revegetation

From a revegetation perspective, we have not yet found sufficient evidence to suggest that the application of treatments in the drawdown zone influenced the use of the drawdown zone by songbirds or terrestrial arthropods.

In general, relative abundance of terrestrial arthropods varied between sites and collection methods. The relative abundance of arthropods was higher in the drawdown zone than upland reference sites at all sites sampled. This does not infer positive treatment effects as relative abundance was higher at control rather than treatment areas for most sites and trap types except for malaise samples at two sites. This may indicate a positive treatment effect for those particular sites but the trend is not supported by pitfall sampling or other analysis. Richness was higher in 2015 than 2013 and varied significantly among sites, and years but not among treatments. Biomass of terrestrial arthropods was also significantly higher in 2015 than in previous years and it varied by site, habitat, and trap type but no clear trend was observed between the control and treatment areas within sites. Overall, no difference was found in the relative abundance, species richness, and biomass of arthropods between treatments.

Relative abundance, richness, diversity, and evenness of songbirds varied by site and habitat type. No clear trend emerged regarding differences between treatments. Additionally, studying nesting success of grass and ground-nesting birds may provide more relevant data with respect to the efficacy of revegetation prescriptions to provide habitat for birds.

As discussed in 2013, measuring ungulate use of the revegetation area was problematic for several reasons as outlined in Adama and Hawkes (2015) and has was removed from sampling. Prescriptions for potential wildlife enhancement projects (Hawkes and Howard 2012) continue to be considered for a wildlife enhancement strategy for mid- and lower Arrow Lakes Reservoir.

There are several possible reasons why there has been little evidence of enhanced wildlife use in the revegetation treatments, including (but not limited to): 1) the size of the revegetation treatments and their proximity to adjacent habitat may limit use by wildlife 2) the size of the revegetation treatments and their proximity to adjacent habitat may limit our ability to detect differences in wildlife use between treatment and control polygons; 3) the type of revegetation prescription (e.g., live stake vs. sedge/grass plug seedling) may not be preferred habitat; 4) the lack of replication at the treatment level makes it difficult to detect a signal, even if one exists; 5) failure of revegetation treatments to establish and low survivorship rates due to natural and anthropogenic stressors and disturbance; and 6) pre-existing differences in site conditions were present prior to treatment application, however, baseline sampling was not conducted to assess pre-treatment variation between control and treatment areas. Until more data are collected to assess the effectiveness of the revegetation program, we will not be in a position to assess the effectiveness of the revegetation program to enhance habitat for wildlife.

Physical Works

Potential wildlife physical works have been identified (Hawkes and Howard 2012) but not implemented. This question cannot be answered until they are implemented and monitored.

6.1.2 If revegetation and the wildlife physical works projects enhance wildlife habitat in the drawdown zone, to what extent does the revegetation program and the wildlife physical works projects increase the productivity of habitat in the drawdown zone for wildlife?

Revegetation

To date, we have not yet found sufficient evidence to suggest that revegetation prescriptions are enhancing wildlife habitat in the drawdown zone. However, 2015 was the first year of bird nest monitoring, thus, future years monitoring songbird nesting success may provide more data with respect to productivity of songbird species in the drawdown zone (particularly within revegetation treatments). The biomass of arthropods also currently provides a measure of habitat productivity. However, there have been no clear trends in arthropod biomass to support increased productivity in the drawdown zone due to the revegetation prescriptions.

Physical Works

Potential wildlife physical works have been identified (Hawkes and Howard 2012) but not implemented. This question cannot be answered until they are implemented and monitored.

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

Revegetation

The application of the revegetation prescriptions does not support a treatment-specific assessment of effectiveness. The ability to answer this question is hampered by the relatively small number of areas treated in the drawdown zone, the size of the areas treated, the lack of replication associated with each revegetation prescription within each site, and the lack of success and low survivorship of revegetation treatments in many polygons under study. This limits the ability to use inferential statistics to determine whether some methods are more effective than others. The best we can do is assess habitat suitability at each site and correlate that to the type of revegetation prescription applied. At present, it is unknown if live-stake or plug seedling prescriptions will be more effective at enhancing wildlife habitat in the drawdown zone.

Physical Works

Potential wildlife physical works have been identified (Hawkes and Howard 2012) but not implemented. This question cannot be answered until they are implemented and monitored.

6.2 Management Questions - Summary

Our ability to address each of the management questions is summarized below (Table 6-1). The methods currently used are appropriate for collecting data that can be used to answer specific questions. For others, additional approaches may be required. For example, to answer questions regarding songbird productivity, nest searches are suggested. In other cases, increasing the total area or number of areas revegetated would assist with problems associated with small sample size and small treatment areas. Continued monitoring of arthropod, songbird, and bat populations in the drawdown zone should provide the necessary information to answer most management questions. As recommended in 2013, sampling for ungulates (via aerial surveys or pellet plots) is not recommended because of the limited influence the revegetation prescriptions are likely to have on ungulate populations. Evidence of use by ungulates can be obtained by recording incidental wildlife sign when sampling for other taxa. Sampling in each year will remove uncertainty associated with bi-annual sampling and better characterize the year-to year variation of all taxa sampled. Modifications to the study are suggested that will provide the data necessary to answer the management questions.

Additionally, until the physical works are implemented in mid- and lower Arrow Lakes Reservoir, we will not be able to answer questions regarding their effectiveness.

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

MQ	Able to Address MQ?	Scope		Sources of Uncertainty
		Current supporting results	Suggested modifications to methods where applicable	
1. Are the revegetation and the wildlife physical works projects effective at enhancing wildlife habitat in the drawdown zone?	Inconclusive	There is evidence of species-specific responses to revegetated areas (more bird nests) but results for other taxa are inconclusive. The data indicate that wildlife is using all habitat types, but current results show little difference between control and revegetation treatment plots. Physical Works: Unknown. Not implemented.	• Pair autonomous acoustic monitors (bats) to sample control and treatment areas simultaneously • Focus sampling on areas where revegetation prescriptions are most successfully established i.e. Lower Inonoaklin, Edgewood South etc.	• Lack of appropriate baseline (sampling did not occur prior to the application of the revegetation prescriptions) • Natural annual population variation and seasonality • Proximity of treatments to adjacent upland habitat • Lack of replication • Success of revegetation program • Bi-annual sampling • Variable reservoir operations • Physical works have not been implemented
2. If revegetation and the wildlife physical works projects enhance wildlife habitat in the drawdown zone, to what extent does the revegetation program and the wildlife physical works projects increase the productivity of habitat in the drawdown zone for wildlife?	Inconclusive	It is unclear if the revegetation prescriptions are effectively improving wildlife habitat. In general, no multi-year trend has been observed for biomass values between control and treatment areas within sites. Wildlife physical works projects are in progress and have yet to be implemented and monitored.	• Increased frequency of sampling (i.e., annually) • Include nest searches to study songbird productivity • Pair autonomous acoustic monitors to sample control and treatment areas simultaneously	• Lack of appropriate baseline (sampling did not occur prior to the application of the revegetation prescriptions) • Natural annual population variation and seasonality • Lack of replication • Success of revegetation program • Bi-annual sampling • Variable reservoir operations • Physical works have not been implemented • Lack of productivity surveys for songbirds (i.e., nest searches)
3. Are some methods or techniques more effective than others at enhancing wildlife habitat in the drawdown zone?	Inconclusive	The application of treatment prescriptions in the drawdown zone does not support a treatment-specific assessment. The prescriptions applied were too small, not well-replicated, nor were they stratified by site.	• Consider adding replicates of certain revegetation prescriptions at some sites • Increase the size (total area treated) of some existing revegetation areas	• Lack of appropriate baseline (sampling did not occur prior to the application of the revegetation prescriptions) • Natural annual population variation and seasonality • Lack of replication • Success of revegetation program • Variable reservoir operations • Physical works have not been implemented

6.3 RECOMMENDATIONS

1. **Consider modifying the sampling program of CLBMON-11B1 to occur annually.** This approach would ensure that appropriate before- and after-impact data are collected at the proposed physical works locations (i.e., Lower Inonoaklin Road, Edgewood South, and Burton Creek). Collecting songbird, and arthropod data on an annual basis would also provide a better indication of the annual variability associated with those species groups and their use of the drawdown zone (with particular emphasis on the use of control and treatment sites). Once the proposed physical works are implemented, annual sampling at those locations would serve to assess the effectiveness of those physical works using a traditional before-after-control-impact (BACI) study design (Smith 2002).
2. **Continue with nest searches to study bird productivity** in the drawdown zone. Specifically target revegetated areas – Burton Creek, Lower Inonoaklin Road, and Edgewood South.
3. **Consider increasing the total area revegetated** in the drawdown zone (i.e., expand existing treatment areas) or add additional treatment areas of the same prescriptions applied previously to increase the sample size.

7.0 SARA-LISTED SPECIES

7.1 Amphibians and Reptiles

The only amphibian at risk documented in the drawdown zone of Arrow Lakes Reservoir is the Western Toad, which is a species of Special Concern (as per SARA).

Three species of reptiles with federal conservation status were documented in 2015, either in or near the drawdown zone of mid- and lower Arrow Lakes Reservoir:

1. The Western Skink (*Plestiodon skiltonianus*) is blue-listed in British Columbia and is a federal species of special concern. This species was documented at Edgewood North, where it is known to occur.
2. The Rubber Boa (*Charina bottae*) is blue-listed in British Columbia and is listed federally as a species of special concern. In 2015, one individual was recorded at the edge of the drawdown zone at Lower Inonoaklin.

7.2 Birds

Only two species listed by COSEWIC were encountered in 2015: Barn Swallow (Threatened) and Western Grebe (Special Concern). In prior survey years there have been observations of five other COSEWIC listed species: Horned Grebe and Long-billed Curlew (both Special Concern), Common Nighthawk and Bank Swallow (both Threatened), and Black Swift (Endangered). All of these excepting the grebes are also listed under Schedule 1 of the Species at Risk Act. Four of the seven species of COSEWIC-listed species we have detected are aerial insectivores, a foraging guild which has experienced large declines of many species across varied taxonomic groups. Observations of provincially-listed species in 2015 include the blue-listed Barn Swallow, California Gull, and Great Blue Heron, and the red-listed Western Grebe. During previous years we have also recorded the blue-listed Caspian Tern and Long-billed Curlew.

7.3 Mammals

Grizzly bear (*Ursus arctos*) is a blue-listed species of Special Concern in B.C. Although this species was not documented in 2015, it is known from previous years to range the west side of Arrow Lake and has been documented in the drawdown zone of Edgewood South and the drawdown zone and upland area of Mosquito Creek.

Many bat species in B.C. are species at risk. Provincially blue-listed, Townsend's big-eared bat (*Corynorhinus townsendii*) was documented from every site sampled except for one, Burton Creek treatment, which incidentally was the only site it was documented in 2013. Also blue-listed, Western small-footed Myotis (*Myotis ciliolabrum*) and Northern Myotis (*Myotis septentrionalis*) were found at Edgewood N, Edgewood S and Lower Inonoaklin and Fringed Myotis (*Myotis thysanodes*) was documented from Beaton DDZ. Federally endangered species Northern Myotis (*M. septentrionalis*), Little Brown Myotis (*Myotis lucifugus*) and Townsend's Big-eared Bat (*C. townsendii*) were found at Beaton DDZ and all sites sampled, respectively.

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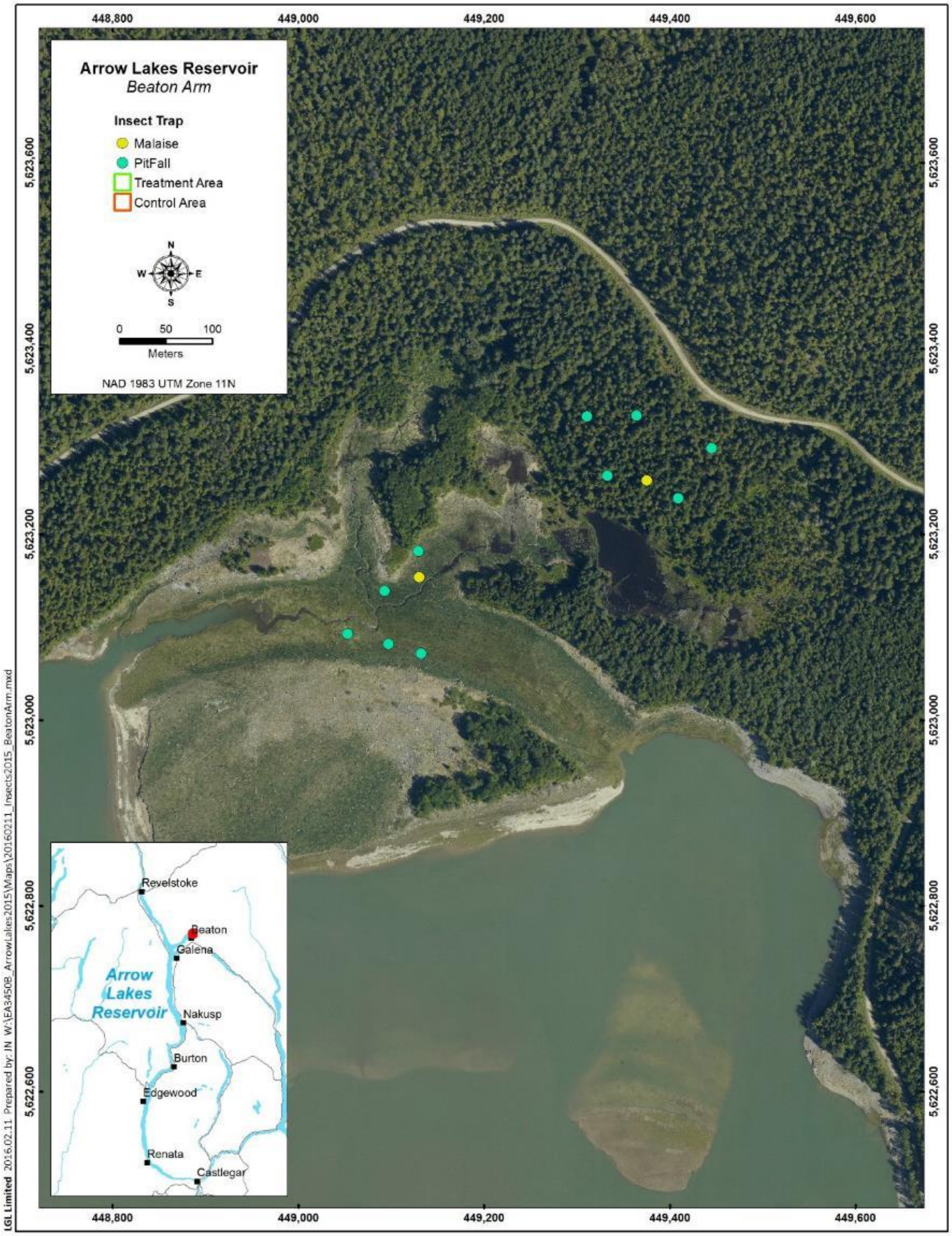
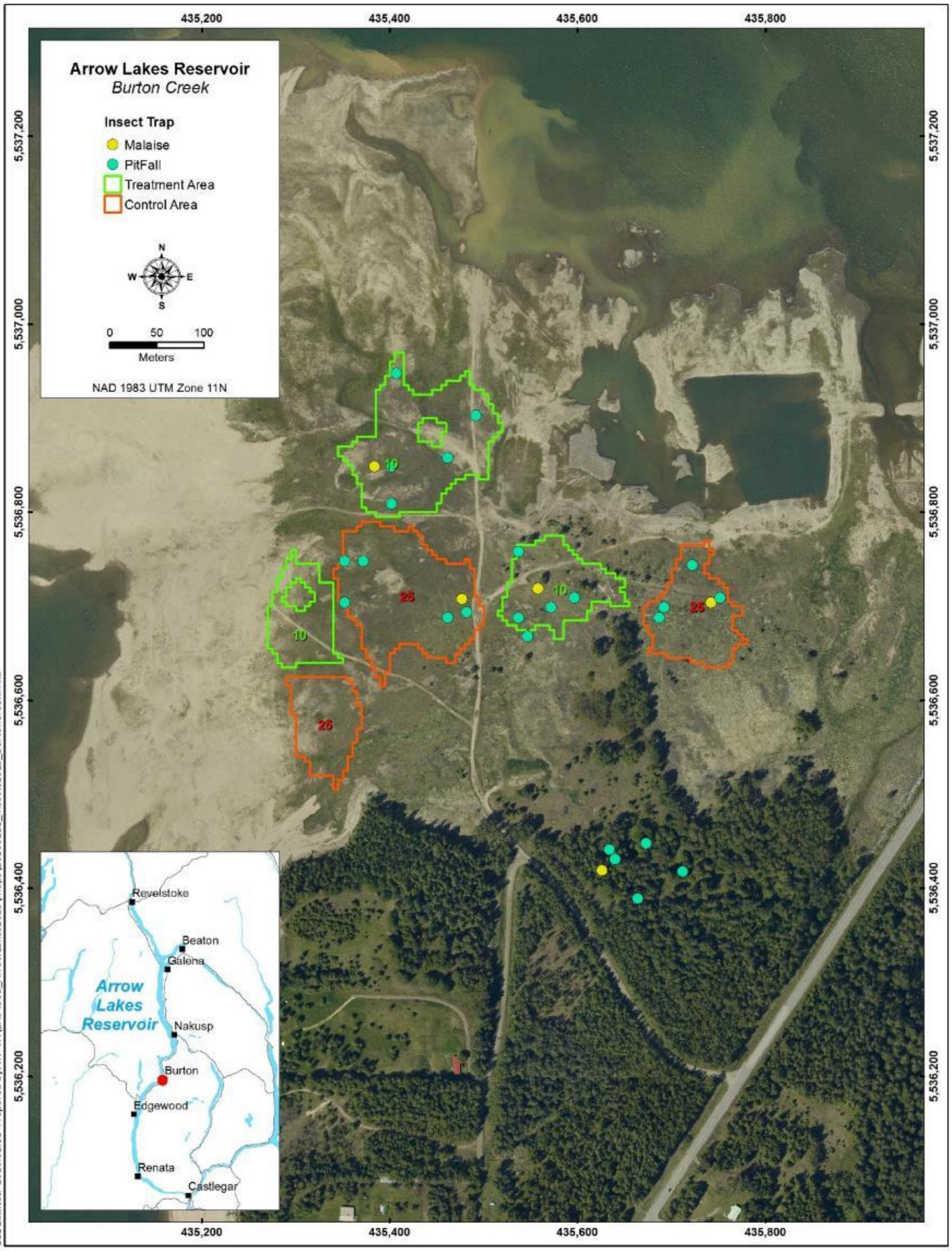
9.0 APPENDICES

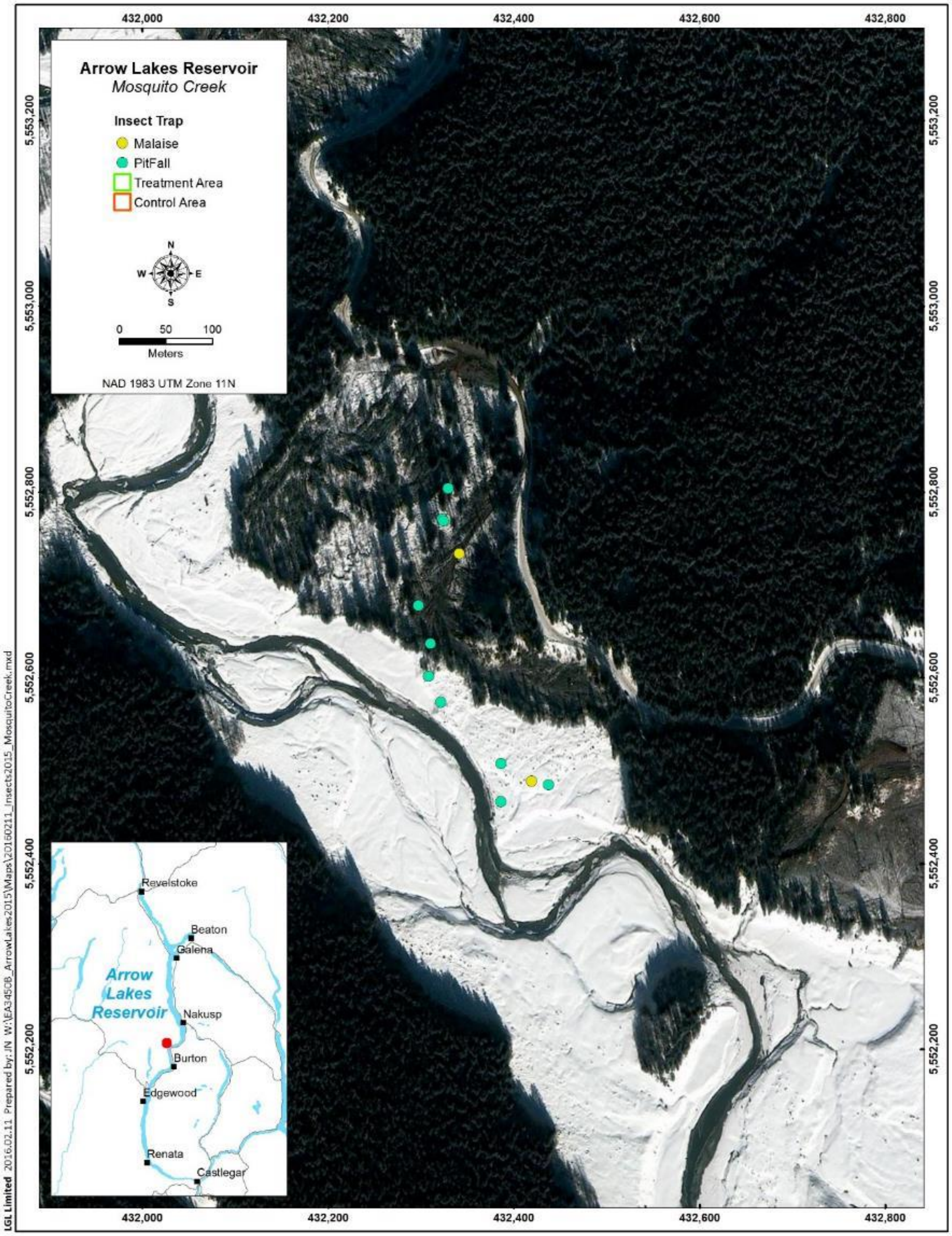
Appendix A: Maps of Malaise and pitfall trap locations for 2015



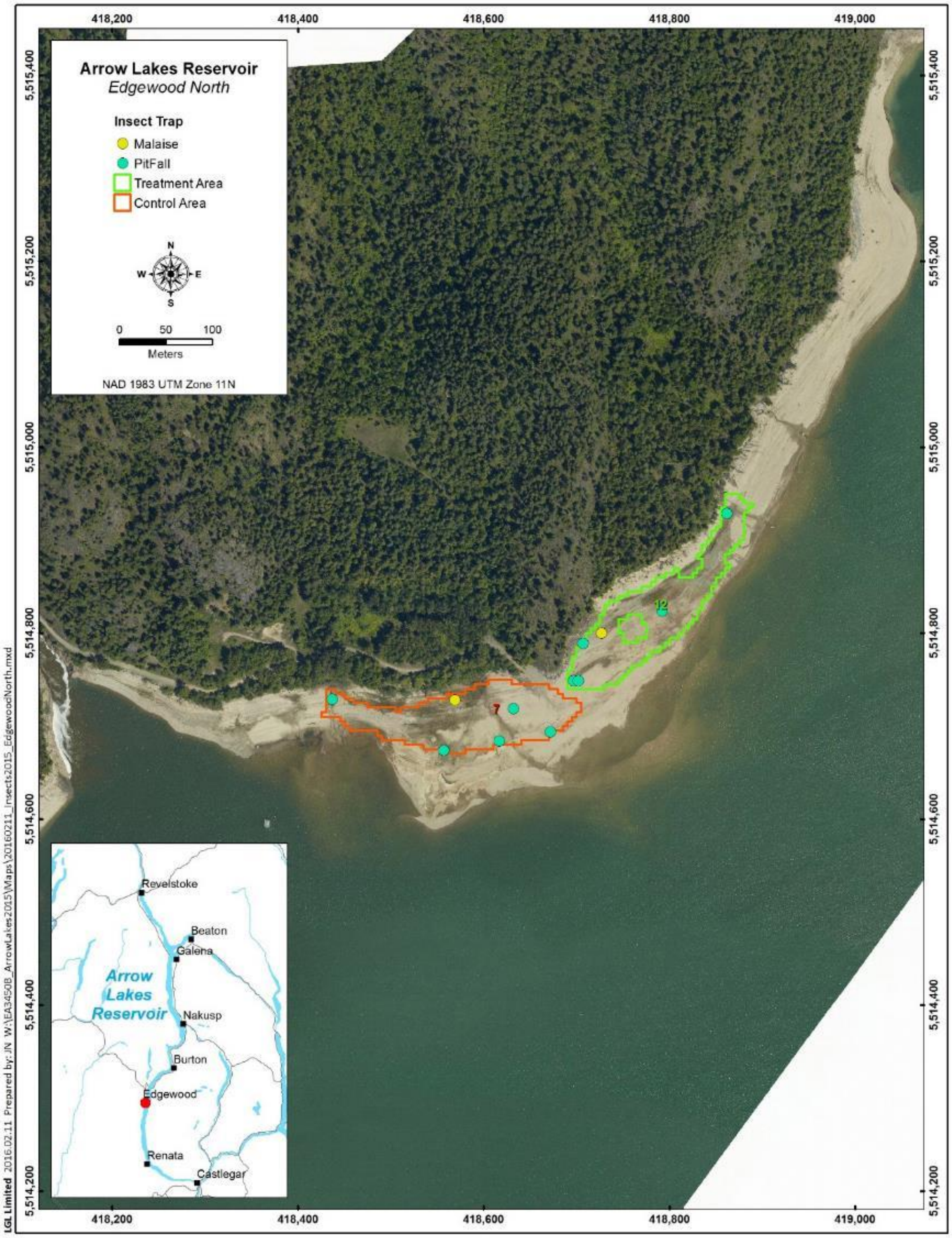
Map 9-1: Distribution of Malaise and pitfall traps installed at Beaton Arm, 2015



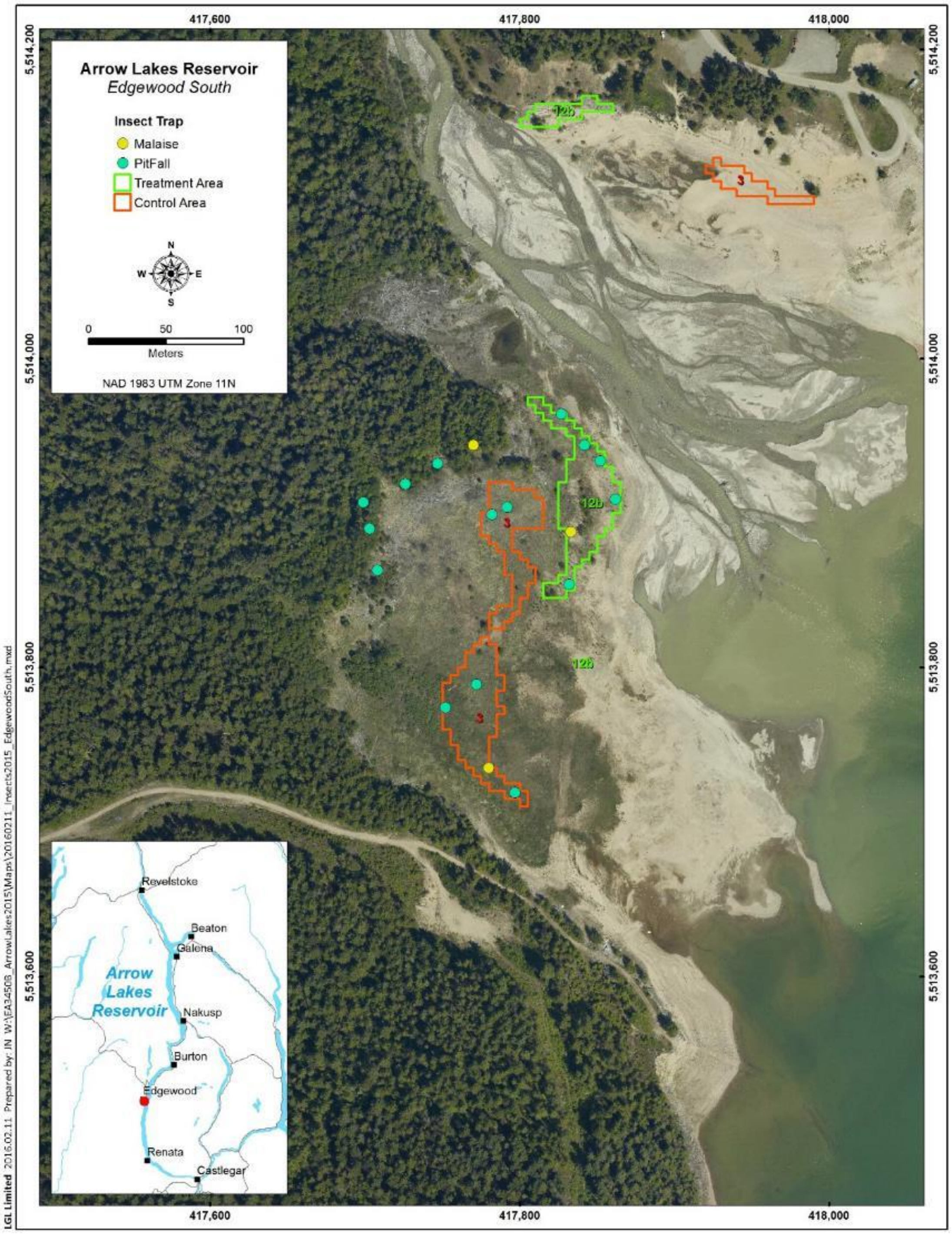
Map 9-2: Distribution of Malaise and pitfall traps installed at Burton Creek, 2015



Map 9-3: Distribution of Malaise and pitfall traps installed at Mosquito Creek, 2015

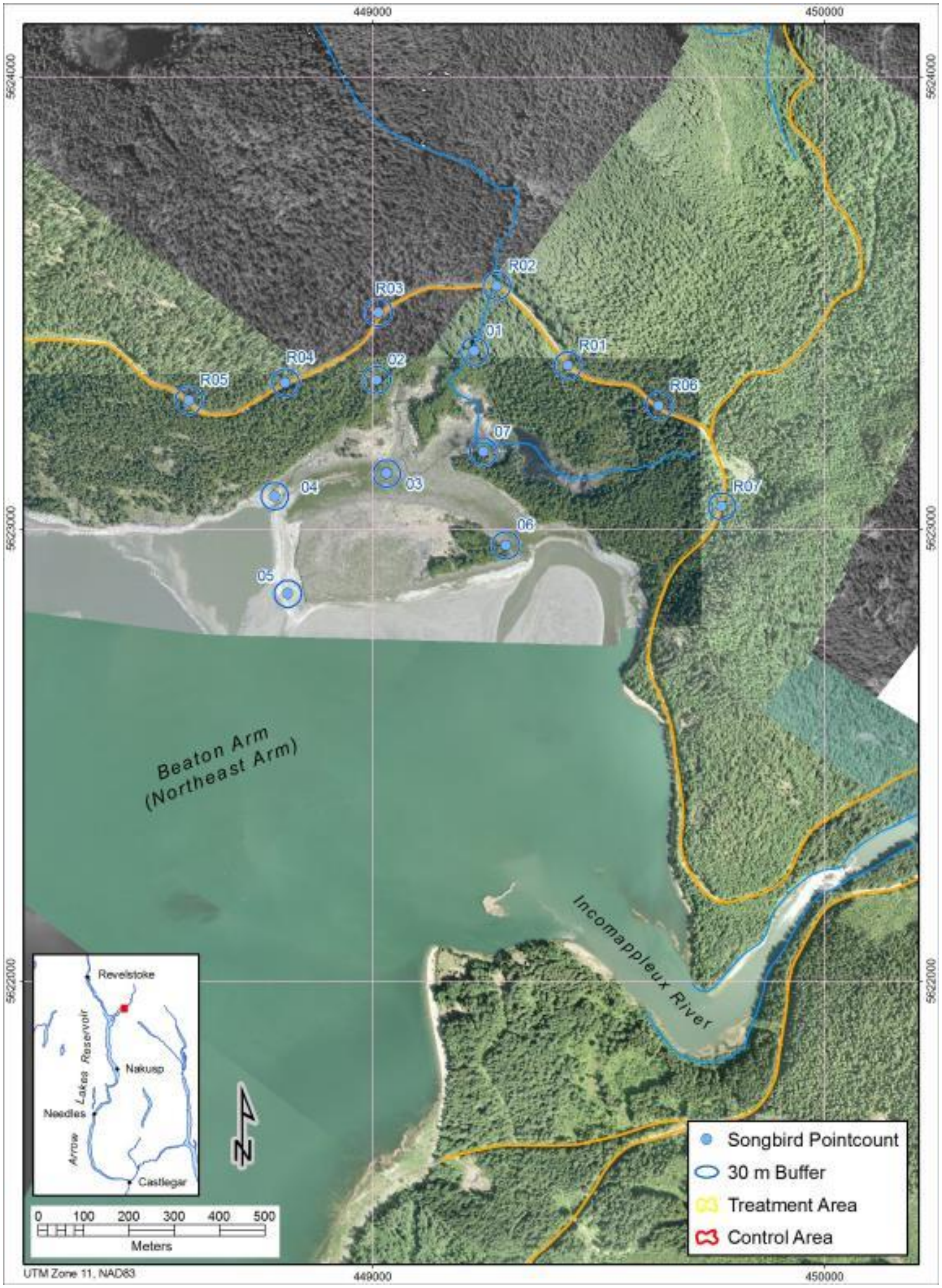


Map 9-4: Distribution of Malaise and pitfall traps installed at Edgewood North, 2015



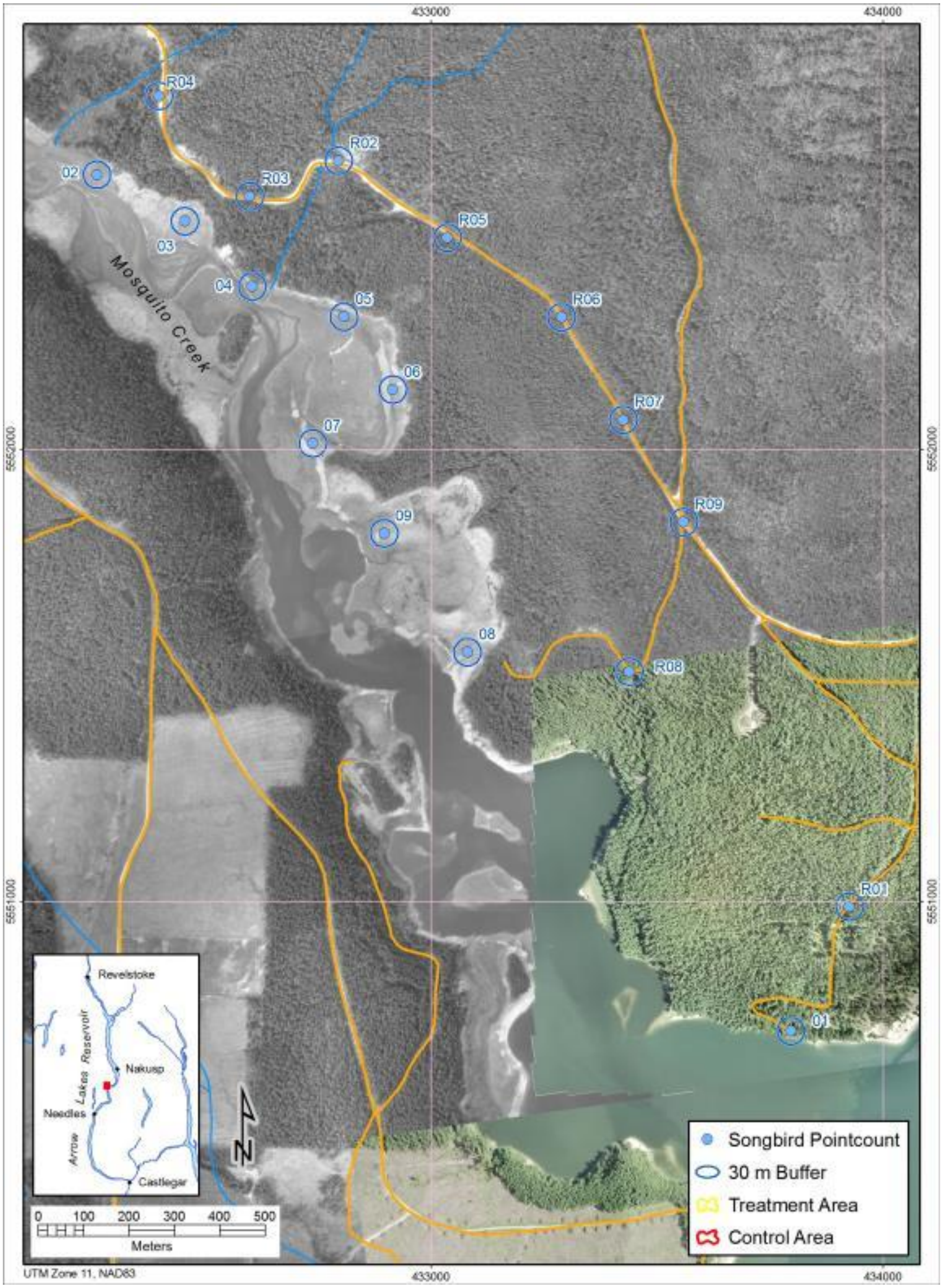
Map 9-5: **Distribution of Malaise and pitfall traps installed at Edgewood South, 2015**

Appendix B: Maps of songbird point count stations for 2015

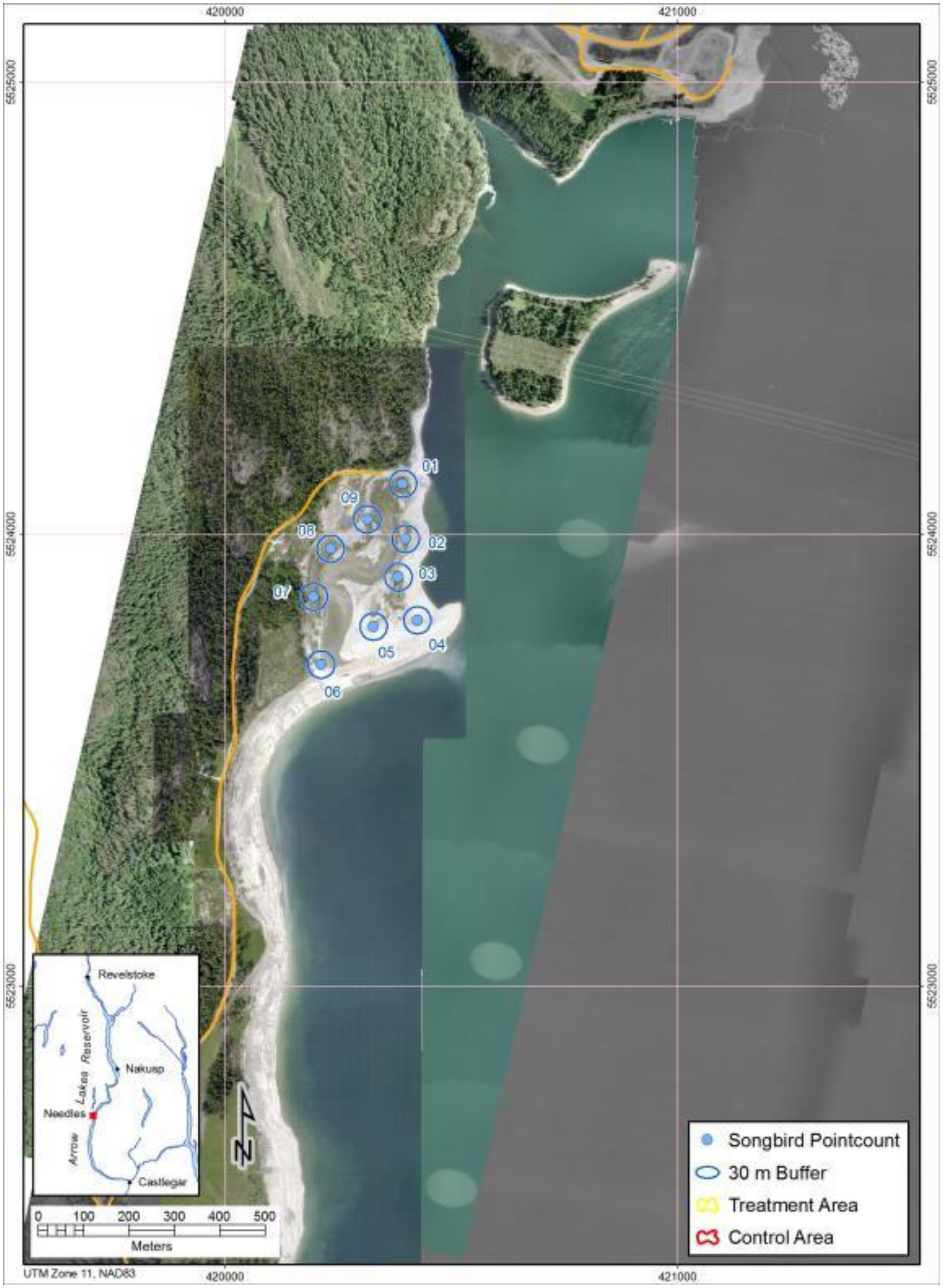


Map 9-6: **Distribution of songbird point count stations at Beaton Arm, 2015.** Note: although a 30 m radius is shown, songbird analyses were constrained to a 75 m radius

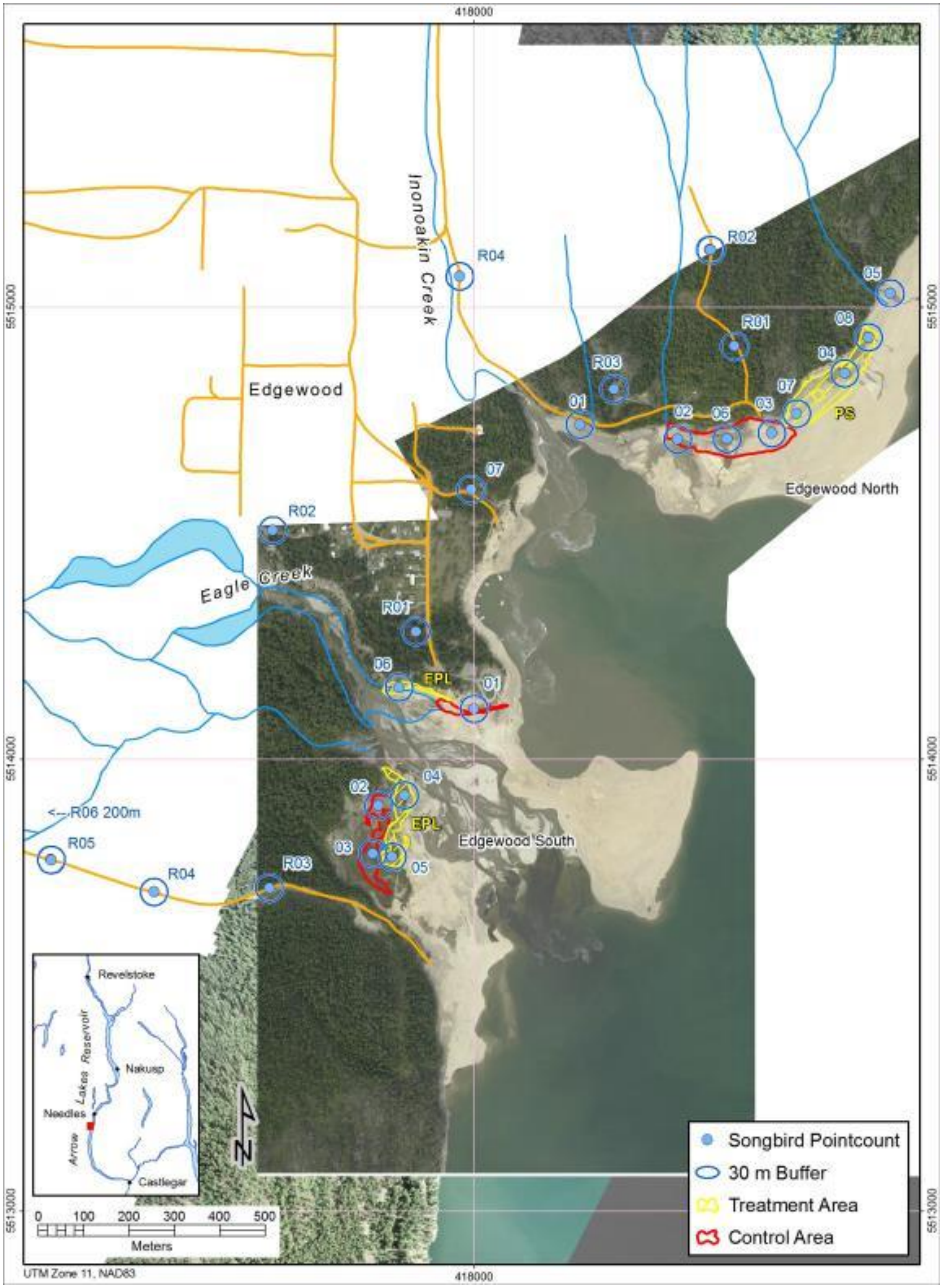
Map 9-7: **Distribution of songbird point count stations at Burton Creek, 2015** Note: although a 30 m radius is shown, songbird analyses were constrained to a 75 m radius



Map 9-8: **Distribution of songbird point count stations at Mosquito Creek, 2015** Note: although a 30 m radius is shown, songbird analyses were constrained to a 75 m radius



Map 9-9: **Distribution of songbird point count stations at Lower Inonoaklin Road, 2015**
Note: although a 30 m radius is shown, songbird analyses were constrained to a 75 m radius



Map 9-10: **Distribution of songbird point count stations at Edgewood (north and south), 2015** Note: although a 30 m radius is shown, songbird analyses were constrained to a 75 m radius