Columbia River Project Water Use Plan

Kinbasket and Arrow Lakes Reservoirs Revegetation Management Plan

Wildlife Effectiveness Monitoring of Revegetation Efforts and Physical Works Trials in Kinbasket Reservoir

Implementation Year 8

Reference: CLBMON-11A

Final Annual Report

Study Period: 2015

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

July 25, 2016

EA3451B

KINBASKET AND ARROW LAKES RESERVOIRS

Monitoring Program No. CLBMON-11A
Wildlife Effectiveness Monitoring of Revegetation in Kinbasket Reservoir

Final Report

2015

Prepared for

BC Hydro

BC Hydro Generation

Water Licence Requirements
6911 Southpoint Drive
Burnaby, BC

Prepared by

Okanagan Nation Alliance

and

LGL Limited environmental research associates

Technical Contact: Virgil C. Hawkes, M.Sc., R.P.Bio.
vhawkes@lgl.com; 1.250.656.0127
ONA Contact: Alan Peatt, R.P.Bio; 1.250.707.0095 x213

July 25, 2016

Suggested Citation:

Wood, C.M., N. Hentze, and V.C. Hawkes. 2016. CLBMON-11A. Kinbasket and Arrow Lakes Reservoirs: Wildlife Effectiveness Monitoring and Enhancement Area Identification for Lower and Mid-Arrow Lakes Reservoir. Annual Report – 2015. LGL Report EA3451B. Unpublished report by Okanagan Nation Alliance, Westbank, B.C. and LGL Limited environmental research associates, Sidney, B.C., for BC Hydro Generation, Water Licence Requirements, Burnaby, BC. 65 pp. + Appendices.

Cover Photographs:

From left to right: Kinbasket Reservoir at Bush Arm, Jumping Spider *Habronattus* sp., Western Tiger Beetle (*Cicindela oregona oregona*), and Savanah Sparrow (*Passerculus sandwichensis*). Photos all taken at Bush Arm study sites, © Charlene Wood, 2015.

EXECUTIVE SUMMARY

The goal of CLBMON-11A is to monitor and assess the efficacy of revegetation efforts (including physical works trials) in increasing the suitability of wildlife habitats in the drawdown zone of Kinbasket Reservoir (i.e., CLBWORKS-1 and CLBWORKS-16). Monitoring under CLBMON-11A was initiated in 2008 and was conducted annually from 2008 to 2012 by Cooper Beauchesne and Associates Ltd. The Okanagan Nations Alliance (ONA), in partnership with LGL Limited environmental research associates, has continued monitoring since 2013.

The objectives of this program include the design and implementation of an eleven-year monitoring program on selected indicator taxa to provide feedback on how to improve habitat for wildlife through adaptive management. Given the apparent failure of previous revegetation efforts, a new approach was required to answer the management questions of CLBMON-11A and the study was re-configured in 2014. The revised study now includes an assessment of the effectiveness of woody debris removal conducted in 2012 and 2014 at Canoe Reach. The wood debris removal treatment was incorporated into the study design as it is thought that the scouring effects of debris deposition and removal owing to variable reservoir levels combined with the presence of the wood itself prevents vegetation establishment and growth. The removal of wood within study sites is expected to promote revegetation, given previous revegetation failures within the drawdown zone.

As predicted in 2014, wood debris distributions shifted in the last reservoir inundation cycle, and as a result, previously cleared sites received new wood debris loads. To prevent annual recurrence of wood deposition on study sites we recommend protection for all treatment (and ideally control) areas to maintain their cleared status for monitoring (or the existing level of wood in controls). Protection would best be achieved by installing log booms which float at the level of the reservoir and prevent additional wood loads from being deposited on the protected site. One treatment area (Valemount Peatlands North [VP-N]) was outfitted with a log boom, and this was the only site that did not have an increased cover of wood debris since 2014.

Vegetation monitoring revealed large increases in herb cover and marginal increases in herb species richness in the wood-debris removal treatment at VP-N. Unfortunately arthropod sampling and bird surveys at VP-N were hampered due to a mass emergence of Western Toad metamorphs from marsh/pond habitat in the wood removal treatment plot. Further monitoring of the log boom enclosed treatment at VP-N and the deposition of wood debris onto treatment plots in other sites will be examined in future years. Additionally, the success of the soil and wood mounding trials and changes in reservoir water levels will affect our ability to monitor taxa changes at these sites.

Overall, 16,783 beetles and spiders were collected in 2015. Together, spider and ground beetle species assemblages were distinct between all treatments at Canoe Reach in 2015, owing to a large number of species responding differentially to each treatment type. Reference sites had the most unique species. Control plots were more similar in species composition to reference sites than were treatments. Spiders responded similarly to treatments across all sites at Canoe Reach, with the lowest relative abundance of spiders occurring in treatment plots in each site. Treatments were largely characterised by of the ground-running spiders (e.g., *Pardosa* spp.) and bare ground associated beetles

species (e.g., *Bembidion planatum, Cicindela tranquebarica,* and *C. longilabris perviridis*). These species were much more abundant in the drawdown zone than in reference sites and may be useful indicators of vegetation structural changes in treatment areas as they are expected to decline with increased cover of herb and shrub layers. The turnover of arthropod species in treatments will signal changes in habitat quality that may relate to other wildlife in the drawdown zone of Kinbasket Reservoir (increased insect prey for amphibians, reptiles, songbirds, and insectivorous mammals; forage for ungulates; singing perches for songbirds; and nesting sites for sparrows). These patterns will continue to be assessed in the remaining three years of CLBMON-11A.

At Bush Arm, treatment and control polygons were delineated in the drawdown zone, and pre-treatment sampling was conducted in these polygons at five sites in order to assess pre-treatment differences the drawdown zone study plots. Physical works trials (i.e., wood mounds/windrows, live stakes) were implemented at two sites in Bush Arm in the fall of 2015, after surveys were conducted for this year. Thus, this report summarizes the pre-existing differences between focal taxa in the pre-treatment drawdown zone plots at Bush Arm.

Pre-treatment sampling showed similar arthropod species composition between treatment and control plots, with the drawdown zone dissimilar to the assemblages of reference sites. However, site-specific pre-treatment differences are noted with respect to species abundance and richness of arthropods and shrubs at Bush Arm Causeway. Pre-existing differences between treatment and controls and between sites will be considered in the future when evaluating post-treatment responses.

Patterns in the abundance and richness of birds were similar to arthropods, but lack of replication and low bird density in the drawdown zone limited our ability to make strong comparisons. At Canoe Reach and Bush Arm, a few species patterns have emerged that may signal habitat differences in the drawdown zone. Savannah Sparrow, Spotted Sandpiper, and Killdeer were only detected in drawdown zone sites and are expected to respond differently to increased vegetation cover. While Killdeer and Spotted Sandpiper may initially increase in treatments involving woody debris clearing (i.e., at Canoe Reach), they are adapted to nesting in open habitat and are not expected to nest in densely vegetated areas of the drawdown zone. Conversely, Savannah Sparrow is expected to increase with increased cover of grasses and other low vegetation in the drawdown zone. Nesting evidence was relatively low overall, though this may reflect the small size of the plots relative to territory requirements of many breeding bird species. As vegetation establishes on treatment plots, we could see increased utilisation of the drawdown zone by ground or shrub-nesting bird species. We expect that an increase in invertebrate prey (e.g., beetles) on treatment plots with successful revegetation will result in increased detections of those bird species already utilizing the drawdown zone.

Given the apparent failure of previous revegetation efforts, the new approach holds early signs of promise towards providing beneficial enhancements that will allow the management questions to be addressed in full. However, additional years of study are required before conclusions can be reached about the value of woody debris removal, soil and wood mounds/windrows, and success of revegetation in treatment areas. Our ability to address each of the management questions is summarized below, where 'revegetation' includes the physical works programs implemented at Canoe Reach and Bush Arm.

MQ	Able to Address MQ?	Scope		Sources of Uncertainty
		Current supporting results	**Suggested modifications to methods where applicable**	
1: How effective is the revegetation program at enhancing and increasing the utilization of habitat in the drawdown zone by wildlife	Partially	Savannah Sparrow, Spotted Sandpiper, and Killdeer using treatments more than controls Spider and beetle species assemblages are distinct between control and treatment plots at Canoe Reach (one year post-treatment), suggesting major differences in habitat qualities resulting from treatments. Some bare-ground associated arthropods have declined in treatment plots since 2014, possibly due to vegetation cover increases	• Sample treated sites and controls annually (reference sites are not variable and can be sampled less frequently) • Treat additional selected sites for physical works and implement pre-treatment sampling • Protect the long-term integrity of study plots in the drawdown zone by installing physical barriers to exclude woody debris from treatment plots and maintain woody debris in control plots (e.g., install log booms) • Consider the development of physical works prescriptions (e.g., analogous to CLBMWORKS-29B for Arrow Lakes Reservoir) • Catalogue potential revegetation areas (e.g., specific attributes or conditions related to success/failure of revegetation prescriptions)	• Lack of sampling prior to the application of the prescriptions at Canoe Reach • Natural annual population variation • Variable reservoir operations • Bi-annual sampling • Relationships between revegetation or woody debris removal success and site-specific characteristics (e.g., substrate type, soil moisture, aspect, landscape position, etc.) • No measures taken to ensure the long-term integrity of some study plots in the drawdown zone (e.g., log booms)
2: To what extent does revegetation increase the availability of invertebrate prey in the food chain	Partially	General arthropod relative abundance and biomass did not differ between treatment and control transects in revegetation areas (studied prior to 2014). Since 2014 wood removal at Canoe Reach, some sites show clear differences in arthropod abundance between treatment and control areas. Arthropod densities are expected to increase in treatment plots (relative to controls) where vegetation establishment is successful. Results of CLBMON-11B1 show support for correlation between insect biomass and songbird presence (e.g., Hawkes et al. 2012).	• Annual sampling at least of drawdown zone treatment and controls • Select additional sites for physical works and implemented pre-treatment sampling (e.g., woody debris removal) • Consider planting areas with high likelihood of success (i.e., Valemount Peatland North, where substrates are organic, vegetation is colonizing, a log-boom is setup to exclude wood debris, and arthropod abundance is high)	• Lack of sampling prior to the application of the revegetation prescriptions and woody debris removal • Annual population variation • Sampling frequency and variable arthropod phenology • Variable reservoir operations
3: Are revegetation efforts negatively impacting wildlife in the drawdown zone?	Partially	While some species are expected to decline overtime in treatment plots (initial bare-ground colonising arthropod species, exotic species), there is no evidence of negative impacts to wildlife caused by treatment prescriptions	• Management question is better-suited to other studies that currently occur in the region	• Lack of sampling prior to the application of the revegetation prescriptions and woody debris removal • Natural annual population variation • Lack of knowledge regarding wildlife use of the drawdown zone in the winter • Variable reservoir operations

MQ	Able to Address MQ?	Scope		Sources of Uncertainty
		Current supporting results	Suggested modifications to methods where applicable	
4: Which methods of revegetation are most effective at enhancing and increasing the utilization of wildlife habitat in the drawdown zone	Partially	The effectiveness of woody debris removal is likely dependent on site-specific attributes and whether measures are put in place to exclude wood accumulation during subsequent reservoir cycles. Woody debris removal appears to be initially effective at Valemount Peatland North, based on observation of high arthropod and amphibian abundance in the wood removal area since 2014. The effectiveness of physical works trials implemented at Bush Arm will be assessed in future years	• Protect the long-term integrity of study plots in the drawdown zone: install physical barriers to exclude woody debris from treatment plots and maintain woody debris on control plots (e.g., install log booms, where possible) • Select additional sites for physical works and implement pre-treatment sampling (e.g., woody debris removal) • Characterize and catalogue site-specific attributes for all study areas in Kinbasket Reservoir, in order to understand differential responses to treatments	• Lack of sampling prior to the application of the revegetation prescriptions and woody debris removal • No measures taken to ensure the long-term integrity of treatment areas at all study sites • Relationship between revegetation or woody debris removal success and site-specific characteristics (e.g., substrate type, soil moisture, aspect, landscape position, etc.)

Monitoring under CLBMON-11A is currently scheduled to continue in 2016. The following is a summary of the recommendations made for the implementation of CLBMON-11A in future years:

1. **Increase number of treatment site applications** (woody debris removal and/or mound and windrow sites) for replication and to include sites with other soil seed bank profiles, soil fertility assays, evidence of nascent vegetation establishment, and recent land use history. For example, Pond 12 in Valemount Peatland and the west bank of the Bush Arm Causeway are prime sites for expanding the woody debris removal program for enhancement of wildlife habitats in the drawdown zone. In particular, the enhancement of these areas will benefit breeding amphibian and reptile populations.
2. **Implement pre-treatment sampling** for any new sites selected for treatment application. One of the prior limitations of this program was the lack of pre-treatment data, which makes it difficult to determine if any observed changes are treatment effects or related to pre-existing phenomena. Canoe Reach control and treatment plots are paired, but there are statistical and interpretation benefits in sampling the exact same plot both prior to and after woody debris removal. At Bush Arm we implemented pre-treatment sampling which will greatly improve our ability to decipher post-treatment responses.
3. **Monitor KM 88 in Bush Arm** to assess wildlife use of the areas treated in 2013, which represent a different prescription (larger sedge plugs, larger area, and higher density of planting).
4. **Consider additional physical works prescriptions** for the drawdown zone of Kinbasket Reservoir. Developing prescriptions to protect or enhance high quality habitats that exist in the drawdown zone (e.g., Ptarmigan Creek, Bush Arm Causeway, Ponds in the Valemount Peatland) would contribute to an overall improvement in wildlife habitat suitability (if the physical works are built). For example, log booms should be installed at select sites to exclude additional log accumulation and woody debris should be removed from ponds at the Bush Arm Causeway. Current assessments will guide whether prescriptions will be replicated in additional sites.

5. **Catalogue the current state of knowledge of revegetation areas.** The revegetation program would benefit from a review of current knowledge of revegetation prescriptions at all study sites in the drawdown zone of Kinbasket Reservoir. This would provide guidance in areas to target for enhancing success of revegetation.
6. **Increase the total revegetated area in select areas of the drawdown zone.** Following the cataloguing of revegetation areas, we recommend 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 number of replicates. Increasing the extent of revegetation areas will increase the likelihood of detecting any changes in wildlife utilization.
7. **Future revegetation.** Some areas might benefit from revegetation post-treatment (physical works trials). The current treatment plots could be split into planted (enhanced revegetation) and un-planted (natural revegetation) treatment areas. Revegetation efforts should be site-specific based on a prescription for that area. If future revegetation is to occur, consider the species of wildlife that are likely to benefit from the revegetation to ensure the appropriate mix of plants is used, that the total area planted is likely to influence wildlife use of the drawdown zone, and that the revegetation prescriptions be applied in a replicated manner with sufficient stratification. Assessing the efficacy of this future revegetation would require long-term monitoring beyond the current scope of this project.

Key Words: Kinbasket Reservoir, arthropods, ungulates, songbirds, woody debris, revegetation, physical works, effectiveness monitoring, drawdown zone, hydro

ACKNOWLEDGEMENTS

The authors express their appreciation to the following individuals for their assistance in coordinating and conducting this study: Margo Sadler, Guy Martel, Mark Sherrington, Phil Bradshaw, and Dean den Biesen (BC Hydro); Dave Craig and Leona Marsden (Spaz Logging); Alan Peatt, Alexis Friesen, Joey Chisholm, and Andrew 'Oly' Clarke (Okanagan Nation Alliance); Murray Chapple (Sterling Lumber); Robb Bennett and Claudia Copley (Royal British Columbia Museum); Andrew Davis, Michael Miller, Jamie Fenneman, Wendell Challenger and Julio Novoa (LGL Limited).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACRONYMS AND DEFINITIONS

The following terminology is used throughout this report. Definitions are presented in a logical, not alphabetical, order.

Revegetation or Revegetation Program: prior to 2014, the CLBWORKS-1 revegetation program entailed planting the drawdown zone areas of Kinbasket Reservoir in efforts to establish vegetation and enhance the drawdown zone for wildlife use. Since 2014, the terms ‘revegetation’ and ‘revegetation program’ are extended to include other aspects of CLBWORKS-1 and CLBWORKS-16 implemented in 2014 and 2015, such as physical works treatments (wood debris removal, wood debris and soil mounds/windrows).

Drawdown Zone: the terrestrial portion of the reservoir that is inundated and exposed due to changing reservoir elevations, typically between 707.41–754.38 m ASL.

Upland: non-reservoir habitats above the drawdown zone that contain Reference Transects (see below).

Reach: refers to a broad geographic area of the reservoir used as the highest level of stratification for sampling. Two reaches within Kinbasket Reservoir were sampled for CLBMON-11A: Canoe Reach in the north and Bush Arm in the south. Specific sites are sampled within each reach.

Site: Sampling area within a reach in which treatments were applied and/or upland areas sampled. There are currently five sites monitored at Canoe Reach, which are abbreviated as follows:

- **VP-N:** Valemount Peatland North
- **VP-S:** Valemount Peatland South
- **PS-N:** Packsaddle Creek North
- **PS-S:** Packsaddle Creek South
- **YJ:** Yellowjacket Creek

The five sites are monitored at Bush Arm are abbreviated as follows:

- **CHT:** Chatter Creek
- **BAC-N:** Bush Arm Causeway North (northwest)
- **BAC-S:** Bush Arm Causeway South (southwest)
- **GDF:** Goodfellow Creek
- **HOPE:** Hope Creek

Pre-treatment: Sampling that occurred within a site prior to application of revegetation or physical works trials.

Treatment Type: Sampling location within a site consisting of one of three main treatment types, i.e., treatment, control, and reference, defined as follows:

- **Treatment.** Wood debris removal or wood debris and soil mound/windrow creation in the drawdown zone (<754 m ASL).

- **Control:** drawdown zone area adjacent to Treatment areas where woody debris was not removed and/or soil and wood mound/windrows were not created. These areas are situated at approximately the same elevation as the Treatments.
- **Reference:** These areas are immediately upland of the treatment and control sites and are representative of the non-drawdown zone, forested condition. These sites represent what would be in the drawdown zone if the reservoir was not there.

Additionally, sampling sometime occurred in the drawdown zone where treatment and control plots were not designated. These locations are referred to as**:**

- **Drawdown Zone (DDZ):** area of the drawdown zone that was sampled but not within a defined treatment or control area

1.0 INTRODUCTION

Kinbasket Reservoir is located in southeast British Columbia between the towns of Donald and Valemount. The reservoir was created in 1974 to serve as the primary storage reservoir for power generation on the Columbia system. The 216 km reservoir is licensed to fluctuate 46.9 meters in elevation (the drawdown zone) throughout a year, resulting in erosion and habitat degradation in the reservoir's upper elevations (741—754 m ASL) (BC Hydro 2005). A Water Use Plan (WUP) was developed in 2007 as a result of a multi-stakeholder consultative process to determine how to best operate BC Hydro's facilities on the Columbia River to balance environmental values, recreation, power generation, culture/heritage, navigation and flood control (BC Hydro 2007). The process involved a number of interest groups, First Nations, government agencies and other stakeholders collectively referred to as the Consultative Committee (CC)[1]. The goal of the WUP was 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).

During the water use planning process, both the need and opportunity to improve wildlife habitat in the upper elevations of Kinbasket Reservoir were recognized (BC Hydro 2005). The CC reviewed the operating alternatives and supported the implementation of physical works in the Kinbasket Reservoir to help mitigate impacts to wildlife and wildlife habitat in lieu of changing reservoir operations. The CC supported a reservoir-wide planting program (CLBWORKS-1) compatible with both the current operating regime and proposed operating alternatives to improve vegetation growth in the drawdown zone. Recognizing the need to assess the effectiveness of this program, the CC also recommended a number of studies to monitor and "audit" the effectiveness of planting efforts on vegetation communities and wildlife habitat use. This recommendation resulted in the creation of several monitoring programs including CLBMON-9 to assess the effectiveness of revegetation treatments in establishing vegetation communities within the drawdown zone, and CLBMON-11A, an 11-year monitoring program to assess the revegetation program effectiveness at increasing wildlife utilization within the drawdown zone of Kinbasket Reservoir. The terms of reference for CLBMON-11A (BC Hydro 2008) also states that this study's results will aid in more informed decision-making with respect to the need to balance 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 decision affected by the findings of CLBMON-11A is whether revegetation, in lieu of changes to reservoir operations, is effective at enhancing wildlife habitat and reducing the negative effects of reservoir operations on wildlife. Results from this study will also support an adaptive management approach in refining the objectives and methods for enhancing wildlife habitat in the drawdown zone.

The terms of reference for CLBMON-11A (BC Hydro 2008) describe the objectives of the monitoring program, identify a suite of focal taxa (amphibians, birds, small mammals, ungulates, and invertebrates) and provide

---

[1] The Okanagan Nation Alliance did not participate in this process.

recommendations for the study's implementation. A study design was developed in 2008 that monitors the response of terrestrial arthropods, small mammals and ungulates at control, treatment, and local reference sites (CBA 2010a). Monitoring was conducted annually from 2008 to 2012 by CBA (CBA 2009a, 2010b, 2011a,b) and by the Okanagan Nation Alliance and LGL Limited in 2013. Based on the conclusions and recommendations in Hawkes et al (2014), BC Hydro agreed that the methods applied during the first five years of the program were not well suited to answering the management questions associated with CLBMON-11A. For example, the wrong species of small mammal were being targeted, the productivity (i.e., seed load) of plants that would be consumed by granivorous small mammals had not been assessed, songbirds had not been considered as focal taxa, and the size of the revegetation prescriptions applied in the drawdown zone were likely of little benefit to ungulates given the proximity and spatial extent of suitable habitat adjacent to the drawdown zone. Overall, there did not appear to have been a connection made between the types of plants used in the revegetation program (CLBWORKS-1) and how the use of those species would benefit wildlife using the drawdown zone of Kinbasket Reservoir. In addition, the revegetation program has not been successful (Hawkes et al. 2013) and there was a need to adapt CLBMON-11A to ensure that data collected could be used to answer each of the management questions.

Starting in 2014 an assessment of the effectiveness of woody debris removal to promote the establishment and development of vegetation in the drawdown zone was initiated, as was the efficacy of a log debris boom to prevent the accumulation of woody debris, which would also function to promote the establishment and development of vegetation in the drawdown zone. The focal taxa selected to study the efficacy of woody debris removal and log boom installation were spiders, beetles, and birds (includes songbirds, grouse, waterfowl, shorebirds, etc.). Vegetation data were also collected, but will be assessed under CLBMON-9, with those results provided to CLBMON-11A to enable correlations between vegetation species composition and structure and the selected fauna. All of the taxa selected for study under CLBMON-11A have been studied in Kinbasket Reservoir since 2008 relative to both the revegetation trials, and more recently, the physical works (i.e., woody debris removal and log boom installation) trials.

Major changes applied in 2015 include the removal of ungulate pellet plots for indication of revegetation effectiveness or habitat change in the drawdown zone and a modification of the bird survey methodology. The size of the treatments applied and proximity of highly suitable ungulate habitat adjacent to the reservoir reduces the likelihood that any treatments applied in the drawdown zone are going to infer a net ecological benefit to ungulates. Similarly, the number of ungulate pellet plots required to obtain a sample that would be large enough to assess treatment effects is not attainable under current conditions (see further discussion in Hawkes and Adama 2014). Sign of ungulate (and other wildlife) use of the drawdown zone will continue to be recorded during incidental observations at all monitoring locations.

2.0 OBJECTIVES AND MANAGEMENT QUESTIONS

The overarching goal of CLBMON-11A is to monitor and audit the efficacy of revegetation efforts (including physical works trials) in increasing the suitability of wildlife habitats in the drawdown zone of Kinbasket Reservoir. The objectives of this program include the design and implementation of an 11-year monitoring program for selected indicator taxa to facilitate the assessment of the treatments' success and provide feedback on how to improve habitat for wildlife through adaptive management. More specifically, the objectives as stated in the terms of reference are three-fold:

1. Develop an effectiveness-monitoring program to assess whether revegetation efforts in the drawdown zone of Kinbasket Reservoir improve habitat for wildlife.
2. Assess how effective the revegetation efforts are at improving habitat for wildlife in the drawdown zone between 741 m and 754 m ASL elevation.
3. Report and provide recommendations on the effectiveness of the revegetation program on improving habitat for wildlife in the drawdown zone in Years 5 and 10 (2012 and 2018, respectively)[2].

CLBMON-11A was initiated in 2008 and Objective 1 was completed with refinements to the study design incorporated annually. The monitoring of focal taxa was performed between 2008 and 2015 with some modifications to the effectiveness monitoring program which were provided in Hawkes et al. (2013) and Wood et al. (2015).

2.1 Management Questions and Hypotheses

To meet the objectives of the monitoring program, BC Hydro identified several key management questions and four associated management hypotheses that were designed to help address both the management questions and the study objectives.

The four management questions, here with the 2014 modifications (strike-through/bold), are:

1. How effective is the revegetation program at enhancing and increasing the utilization of habitat in the drawdown zone by wildlife such as amphibians, birds, ~~small mammals~~, and ungulates?
2. To what extent does revegetation increase the availability of invertebrate prey (e.g. arthropods) in the food chain for birds, amphibians ~~and small mammals~~?
3. Are revegetation efforts negatively impacting wildlife in the drawdown zone? For example, does revegetation increase the incidence of nest mortality in birds or create sink habitat for amphibians?
4. Which methods of revegetation **or woody debris removal** are most effective at enhancing and increasing the utilization of wildlife habitat in the drawdown zone?

The management hypotheses to be tested by this study include:

H_1: Revegetation does not increase the utilization of habitats by amphibians in the drawdown zone.

---

[2] The 5-year report that was to be developed in 2012 was deferred.

H_{1A}: Revegetation does not increase species diversity or seasonal (spring/summer/fall) abundance of amphibians in the drawdown zone.

H_{1B}: Revegetation does not increase the abundance of amphibian prey (e.g. arthropods).

H_{1C}: Revegetation does not increase amphibian productivity (e.g., egg laying and young of year survival).

H_{1D}: Revegetation does not increase the amount of amphibian habitat in the drawdown zone.

H_2: Revegetation does not increase the utilization of habitats by birds in the drawdown zone.

H_{2A}: Revegetation does not increase the species diversity or abundance of birds utilizing the drawdown.

H_{2B}: Revegetation does not reduce nest mortality of birds that nest in the drawdown zone.

H_{2C}: Revegetation does not increase the survival of juvenile birds in the drawdown zone.

H_{2D}: Revegetation does not increase the abundance of songbird, shorebird, or marshbird prey (e.g. arthropods).

H_{2E}: Revegetation does not increase the amount of bird habitat in the drawdown zone.

H_3: Revegetation does not increase the utilization of habitats by small mammals in the drawdown zone.

H_{3A}: Revegetation does not increase the diversity or abundance of small mammals in the drawdown zone.

H_{3B}: Revegetation does not increase the abundance of small mammal prey (e.g. arthropods).

H_{3C}: Revegetation does not increase the amount of small mammal habitat in the drawdown zone.

H_4: Revegetation does not increase the utilization of habitat by ungulates in the drawdown zone.

H_{4A}: Revegetation does not increase the seasonal abundance (winter/spring) of ungulates in the drawdown zone.

H_{4B}: Revegetation does not increase the abundance (tonnes per hectare) of ungulate forage.

H_{4C}: Revegetation does not increase the amount of ungulate habitat in the drawdown zone.

H_5: Revegetation does not increase the area of extent of high value wildlife habitat in the drawdown zone.

Management question 4, “Which methods of revegetation are most effective at enhancing and increasing the utilization of wildlife habitat in the drawdown zone” is not associated with a management hypothesis, but will be addressed under

CLBMON-11A. Management hypotheses testing whether the amount of habitat has changed for each indicator taxon (i.e., H_{1D}, H_{2E}, H_{3C}, H_{4C}) are not addressed by CLBMON-11A, however hypothesis H_5 that generally evaluates amount of high value wildlife habitat will be evaluated.

As described in the terms of reference several of the indicator taxa will be monitored under separate Water Licence Requirements (WLR) monitoring programs (e.g., CLBMON-37/58 monitors amphibians and reptiles; CLBMON-36 monitors nest mortality in birds). Consequently, CLBMON-11A does not monitor specific variables (e.g., nest mortality) related to those taxa associated with these monitoring programs.

2.2 CLBMON-11A Study Limitations and Revised Program

The ability to address the above management questions and hypotheses is constrained by several factors:

- There was no pre-treatment sampling at revegetated areas and woody debris removal areas so comparisons before and after treatments cannot be made.
- The original 14 revegetation sites were not sampled every year and were limited in replication. Thus time series vary across sites and treatments were unequal by sites and year. For example, some control transects were lost because revegetation treatments subsequently occurred at their locations. One site was destroyed by excavators (Windfall Creek) and a new site (Causeway) was added in 2010.
- Revegetated areas were typically too small to effectively influence use by certain species of wildlife (e.g., ungulates, and in most cases, small mammals); therefore it may be difficult to discern a treatment effect for these taxa.

Despite the overall assessment of ineffectiveness and issues associated with the original workplan, opportunities presented themselves to modify the program to assess the use of the drawdown zone by wildlife and to evaluate whether physical works programs, such as the woody-debris removal program (CLBWORKS-16), can effectively enhance wildlife habitat in the drawdown zone.

3.0 STUDY AREA

3.1 Physiography

The Columbia Basin in southeastern British Columbia is bordered by the Rocky, Selkirk, Columbia, and Monashee Mountains. The headwaters of the Columbia River begin at Columbia Lake in the Rocky Mountain Trench, and the river flows northwest along the trench for about 250 km before it empties into Kinbasket Reservoir behind Mica Dam (BC Hydro 2007). From Mica Dam, the river continues southward for about 130 km to Revelstoke Dam, then flows almost immediately into Arrow Lakes Reservoir behind Hugh Keenleyside Dam. The entire drainage area upstream of Hugh Keenleyside Dam is approximately 36,500 km^2.

The Columbia Basin is characterized by steep valley side slopes and short tributary streams that flow into Columbia River from all directions. The Columbia River valley floor elevation ranges from approximately 800 m near Columbia

Lake to 420 m near Castlegar. Approximately 40 per cent of the drainage area within the Columbia Basin is above 2,000 m elevation. Permanent snowfields and glaciers predominate in the northern high mountain areas above 2,500 m elevation. About 10 percent of the Columbia River drainage area above Mica Dam exceeds this elevation.

3.2 Climatology

Precipitation in the basin is produced by the flow of moist, low-pressure weather systems from the Pacific Ocean that move eastward through the region. More than two-thirds of the precipitation in the basin falls as winter snow. Snow packs often accumulate above 2,000 m elevation through the month of May, and continue to contribute runoff long after the snow pack has melted at lower elevations. Summer snowmelt is reinforced by rain from frontal storm systems and local convective storms. Runoff begins to increase in April or May and usually peaks in June to early July, when approximately 45 per cent of the runoff occurs. The mean annual local inflow for the Mica, Revelstoke and Hugh Keenleyside projects is 577 m^3/s, 236 m^3/s and 355 m^3/s, respectively.

Air temperatures across the basin tend to be more uniform than precipitation. The summer climate is usually warm and dry, with the average daily maximum temperature for June and July ranging from 20–32°C.

3.3 Kinbasket Reservoir

The approximately 216 km long Kinbasket Reservoir is located in southeastern B.C., and is surrounded by the Rocky and Monashee Mountain ranges. The Mica hydroelectric dam, located 135 km north of Revelstoke, B.C., spans the Columbia River and impounds Kinbasket Reservoir. The Mica powerhouse, completed in 1973, has a generating capacity of 1,805 MW, and Kinbasket Reservoir has a licensed storage volume of 12 million acre feet (MAF; BC Hydro 2007). The normal operating range of the reservoir is between 707.41 m and 754.38 m elevation, but can be operated to 754.68 m ASL with approval from the Comptroller of Water Rights.

Kinbasket Reservoir is lowest during April to mid-May, fills throughout late spring and early summer, and is typically full by mid- to late-summer (Figure 3-1). Although there is some year to year variation, the general pattern is consistent. In 2012 and 2013 Kinbasket was filled beyond the normal operating maximum (i.e., > 754.38 m ASL) for the first time since 1997; in 2014 water levels were kept below the normal operating maximum.

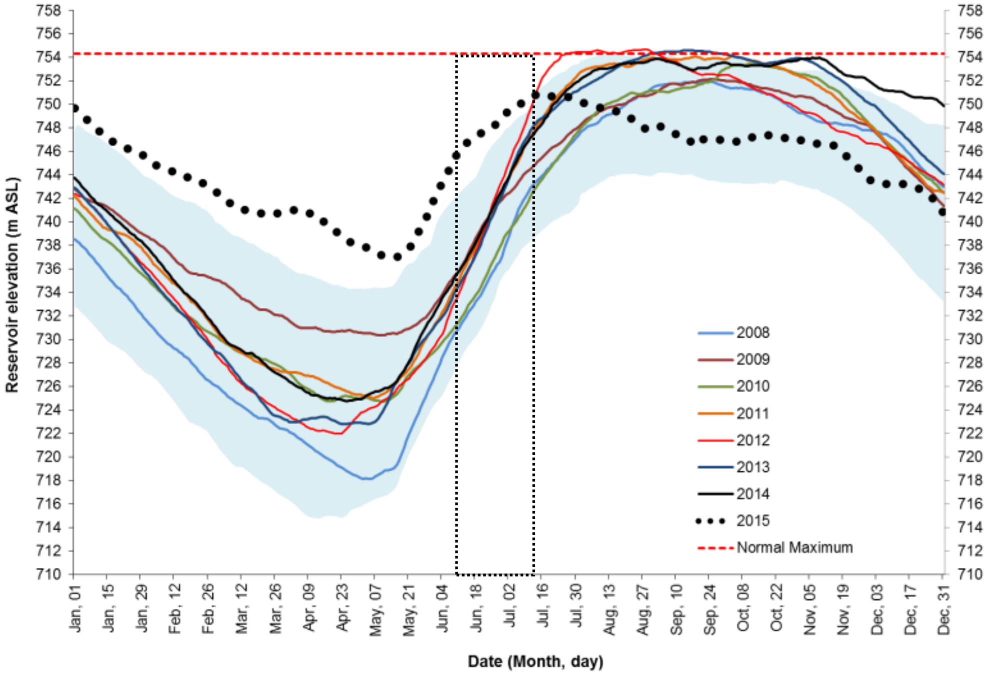

Figure 3-1: **Kinbasket Reservoir hydrograph for the period 2008 through 2015.** The shaded area represents the 10th and 90th percentile for the period 1976 to 2015; the dashed red line is the normal operating maximum; the dashed rectangle encompasses the period of arthropod and bird surveys

3.4 Biogeography

The reservoir is located predominately within the Interior Cedar-Hemlock (ICH) biogeoclimatic (BEC) zone and is represented by four subzone/variants (Table 3-1). The ICH occurs along the valley bottoms and is typified by cool, wet winters and warm dry winters. A small portion of the reservoir extends into the Sub-Boreal Spruce (SBS) BEC zone dh1 variant near Valemount. The climate of the SBS is continental, and characterized by moderate annual precipitation and seasonal extremes of temperature that include severe, snowy winters and relatively warm, moist, and short summers.

Table 3-1: **Biogeoclimatic zones, subzones and variants occurring in Kinbasket Reservoir study area**

SubZone	Zone Name	Subzone/Variant Description
ICHmm	Interior Cedar – Hemlock	mm: Moist Mild
ICHwk1	Interior Cedar – Hemlock	mk1: Wells Gray Wet Cool
ICHmw1	Interior Cedar – Hemlock	mw1: Golden Moist Warm
ICHvk1	Interior Cedar – Hemlock	vk1: Mica Very Wet Cool
ICHmk1	Interior Cedar – Hemlock	mk1: Kootenay Moist Cool
SBSdh1	Sub-Boreal Spruce	dh1: McLennan Dry Hot

3.5 Study sites

The southern end of the reservoir includes Bush Arm and the Columbia Reach. Bush Arm is characterized by flat or gently sloping terrain that was created by fluvial deposition from Bush River and other inflowing streams. These features are often protected from wind and wave action by the islands and peninsulas that protrude along the shoreline. This combination creates the largest variety of valuable wildlife habitat in the entire reservoir. Extensive fens and other wetlands have been identified, and a high diversity of plants is supported (Hawkes et al. 2007).

The extensive Valemount Peatland at the northern end of the reservoir supports the greatest diversity and abundance of wildlife in Canoe Reach. Historically, this peatland was likely a combination of sedge and horsetail fen and a swampy forest dominated by spruce (Ham and Menezes 2008). The wildlife habitat in the peatland varies from highly productive riparian and wetland habitat, to highly eroded sand and cobble parent material. Large areas are virtually devoid of vegetation and portions of the peatland are covered by deposits of wood chips from the breakdown of floating logs (Hawkes et al. 2007). Other notable habitats in the northern end of Kinbasket reservoir include wetlands and ponds on the gently sloping banks along the reservoir’s eastern side. High quality wildlife habitat also occurs near Mica Creek at Sprague Bay and Encampment Creek.

In 2015, surveys were conducted in 10 study sites (Figure 3-2). Five sites were located in Canoe Reach and five sites were located in Bush Arm. Site names and codes are listed in Table 3-2.

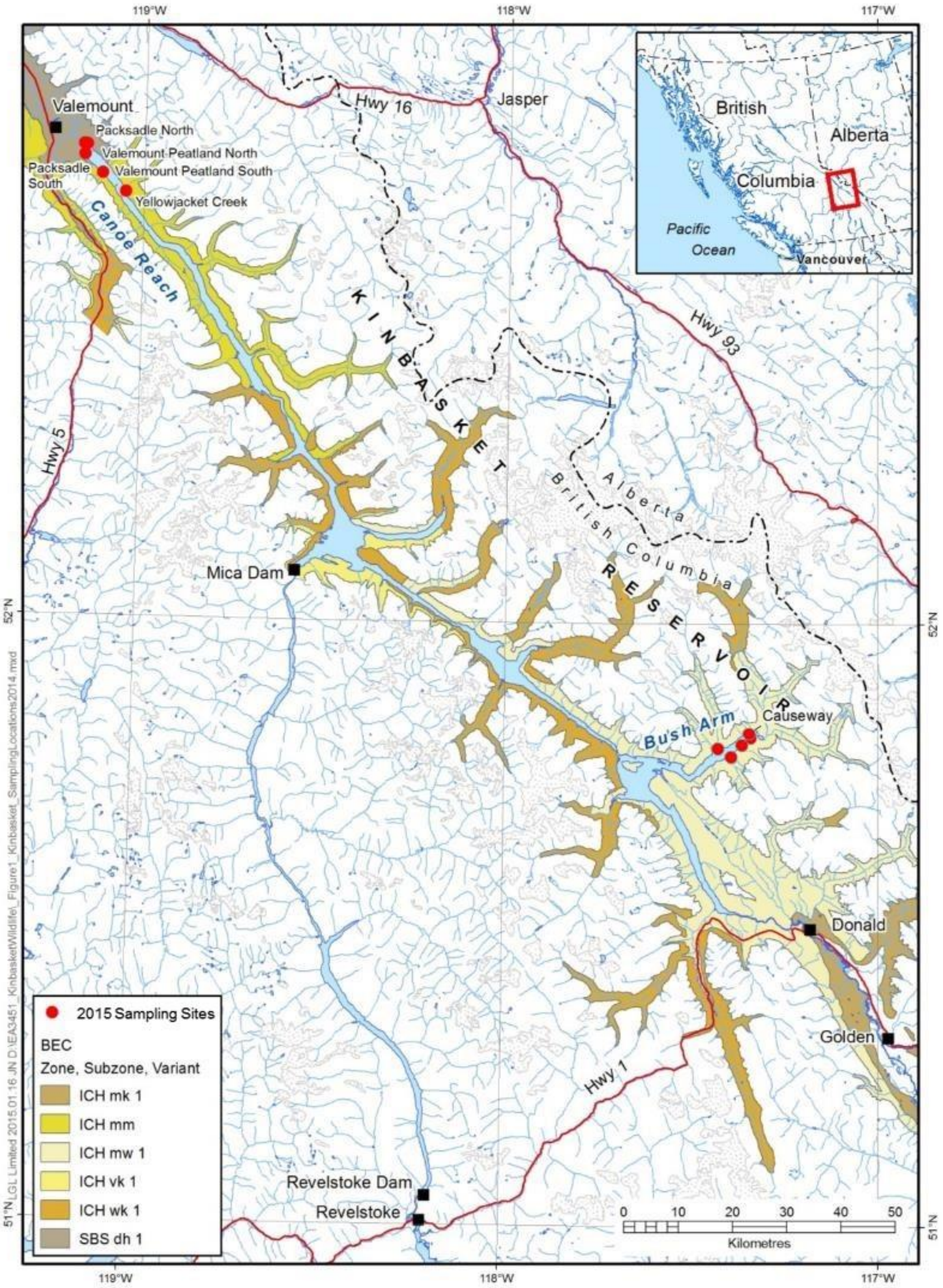

Figure 3-2: **Location of Kinbasket Reservoir in British Columbia and locations sampled for CLBMON-11A in 2015.** Refer to Table 3-1 for descriptions of biogeoclimatic (BEC) zones.

Table 3-2: Sites sampled in 2015 at Canoe Reach and Bush Arm of Kinbasket Reservoir. Plot types are indicated as follows: treatment (T), control (C), and reference (R); DDZ= drawdown zone, UPL= upland forest

	Site	Plot	Plot Description	2015 Surveys
Canoe Reach	Packsaddle North (PS-N)	T	DDZ- woody debris removal (2014)	Arthropods, Birds, Vegetation
		C	DDZ- woody debris accumulation	Arthropods, Birds, Vegetation
		R	UPL- upland forest	Arthropods, Birds
	Packsaddle South (PS-S)	T	DDZ- woody debris removal (2014)	Arthropods, Birds, Vegetation
		C	DDZ- woody debris accumulation	Arthropods, Birds, Vegetation
		R	UPL- upland forest	Arthropods, Birds
	Yellowjacket Creek (YJ)	T	DDZ- woody debris removal (2014)	Arthropods, Birds, Vegetation
		C	DDZ- woody debris accumulation	Arthropods, Birds, Vegetation
		R	UPL- upland forest	Arthropods, Birds
	Valemount Peatland North (VP-N)	T	DDZ- woody debris removal (2014) & log boom installation	Birds, Vegetation
		C	DDZ- woody debris accumulation	Birds, Vegetation
		R	UPL- upland forest	Birds
	Valemount Peatland South (VP-S)	T	DDZ- woody debris removal (2012)	Birds, Vegetation
		R	UPL- upland forest	Birds, Vegetation
Bush Arm	Bush Arm Causeway Northwest (BAC-N)	T*	DDZ- mound/windrow (2015)	Arthropods, Birds, Vegetation
		C	DDZ- unaltered	Arthropods, Birds, Vegetation
		R	UPL- upland forest	Birds
	Bush Arm Causeway Southwest (BAC-S)	T*	DDZ- mound/windrow (2015)	Arthropods, Birds, Vegetation
		C	DDZ- unaltered	Arthropods, Birds, Vegetation
		R	UPL- upland forest	Birds
	Chatter Creek (CHT)	T*/C	DDZ- mound and/or windrow (proposed)	Arthropods[1], Birds[1], Vegetation
	Goodfellow Creek (GDF)	T*	DDZ- mound and/or windrow (proposed)	Arthropods, Birds, Vegetation
		C	DDZ- unaltered	Arthropods, Birds, Vegetation
		R	UPL- upland forest	Arthropods, Birds
	Hope Creek (HOPE)	T*	DDZ- mound and/or windrow (proposed)	Arthropods, Birds, Vegetation
		C	DDZ- unaltered	Arthropods, Birds, Vegetation
		R	UPL- upland forest	Arthropods, Birds

*indicates pre-treatment sampling
[1] polygons for T/C not defined prior to arthropod and avian surveys

4.0 METHODS

The focal taxa selected for study were ground-dwelling spiders and beetles and all breeding birds (songbirds and other birds such as grouse and shorebirds). Spiders and beetles were sampled using pitfall traps and birds via songbird point counts, line transects, and nest searches. The focal taxa align with those sampled under CLBMON-11A in previous implementation years. Differences lie with the removal of small mammals and ungulates as focal groups, focusing on only spiders and beetles, and including ground-nesting songbirds. The focal taxa sampled in 2015 are the same as those sampled in 2014. Vegetation data was collected at each of the treatments under CLBMON-9. Additional environmental and soil substrate data were collected to associate with arthropod and bird responses.

4.1 Environmental Conditions

Temperature and Relative Humidity data were collected during arthropod sampling to supplement arthropod data and assess changes in microclimate of treatments overtime. Onset® HOBO® data loggers (U23-002 HOBO Pro v2 External T/RH) were used in a subset of plots to measure per cent relative humidity and temperature over the period encompassing arthropod and bird surveys. One logger was deployed at the approximate center of each of three treatments at three sites in Canoe Reach in 2014 (VP-N, PS-S, and YJ; n= 9) and 2015 (VP-N, PS-N, and YJ; n= 9). The two sites at Packsaddle Creek (PS-S and PS-N) are approximately 500 m apart and are similar in vegetation and substrate, thus we have used the data from only one logger at Packsaddle Creek for both sites. One logger was also deployed at the approximate center of pre-treatment polygons in Bush Arm (HOPE, GDF, and BAC-N), as well as nearby upland forest sites (reference). Data loggers were held in place at the surface of the soil by attaching the base to a pin flag.

Soil substrate was classified within the quadrats in vegetation transects by estimating per cent cover of the following substrate classes: live organic matter (LOM), dead organic matter, decayed wood, rock, mineral soil, and water. Because vegetation transects did not coincide closely with arthropod sampling in all areas, substrate was also classified within three 1 m x 1 m square quadrats in each arthropod trapping area in 2015 (n= 45 at Bush Arm; n= 27 at Canoe Reach). At Canoe Reach the plots were sampled in the middle of each transect, corresponding to the middle pitfall trap array (A2, B2, C2). At Bush Arm three of the 5 pitfall sampling points were randomly chosen for 1 m x 1 m substrate classification. Classes of substrate were similar to those used in vegetation substrate plots, tailored to suit arthropod associations. Per cent cover of various substrate classes was estimated, including: live organic matter (LOM), moss, lichen, coarse wood (≥10 cm diameter), fine wood (<10cm diameter), rock (gravel/cobbles), mineral soil, fines (mineral/organic mixture), peat, and leaf litter. Additionally, we derived the value of per cent cover of bare ground from these data and per cent canopy cover was estimated above each plot for a comparison of light availability.

4.2 Vegetation

Vegetation sampling was accomplished under CLBMON-9. At Canoe Reach, sampling occurred on June 27-28 and July 13-18 in 2014 and from June 20-22 in

2015. Pre-treatment sampling at Bush Arm occurred on June 24-26 and July 15-18, 2015. Upland reference transects were not sampled for vegetation in 2015.

We used modified belt-line transects to sample vegetation in woody debris treatment, control, and reference plots. At each of the five study areas in Canoe Reach (PS-N, PS-S, VP-N, VP-S, and YJ), three belt transects were established within each control, treatment, and reference area (reference vegetation only sampled in 2014). The number of belt transects established in control and treatment plots at Bush Arm varied in each site because they were stratified within 1-m elevation bands. Most sites had 6 transects (treatments and controls at Bush Arm Causeway North and South, and the treatment at Chatter Creek), however, sample size was 7 for Chatter Creek control, and 12 in controls and treatments at Goodfellow Creek and Hope Creek.

Each belt transect was 20 m long and was sampled using ten 2 m x 0.5 m quadrats in 2014 and five 4 m x 0.5 m quadrats in 2015. All vegetation within or overhanging each quadrat was identified to species, or in some cases to genus, and the per cent cover (to the nearest per cent) visually estimated, along with total covers for each stratum (herbs, shrubs, trees). Herb cover alone was assessed within the belt transects, while cover of woody species was visually estimated within the circular plots, using the same method as for herbs.

4.3 Terrestrial Arthropods

Ground-dwelling (‘epigaeic’) spiders (Araneae), rove beetles (Coleoptera: Staphylinidae), and ground beetles (Coleoptera: Carabidae) are effective focal taxa for habitat monitoring. These taxa are easily and simultaneously sampled using pitfall traps (Marshall et al. 1994), comprise a large proportion of epigaeic arthropod abundance and diversity, occur in almost all terrestrial habitats, include both specialist and generalist species (Niemelä et al. 1993), can be studied across any gradient of habitat change, and respond to both fine-scale and landscape-scale environmental changes. Many other arthropod taxa are also collected by pitfall traps, as well as amphibians and small mammals.

The focal taxa align with those sampled under CLBMON-11A in the previous implementation year (Wood et al. 2015). Differences lie with the lack of species-level identification of rove beetles (Staphylinidae) in 2015 due to budget constraints. The abundance of rove beetles was still assessed as in 2014. Although we were unable to identify the rove beetles from 2015 all specimens were retained in case future opportunity allowed for their examination. Thus, in 2015, we focused on species of spiders and ground beetles (Carabidae).

4.3.1 Sampling Period

Terrestrial arthropods were sampled in two collection periods at Canoe Reach and Bush Arm in 2015 (Table 4-1). The collection periods were run continuously without trap closure between sample collections and total trap-effort was similar for the two reaches (15 days of trapping at Canoe Reach; 16 days at Bush Arm). The hour and minute of setup and collection were recorded for each trap so that trap-hours could be calculated. Trap disturbance resulting in loss of sample (e.g., reservoir inundation or animal disturbance) was recorded in order to account for the reduced sampling effort in data standardizations.

Table 4-1: Sampling period for terrestrial arthropods for 2015. Collection periods were run continuously between sample collection and traps were removed at the end of the second collection period

Reach	Trap installation	First collection	Second collection	Total trap-effort
Canoe Reach	June 16,17,18	June 25,26	July 3,4	
		~ 8 days	~ 7 days	~15 days
Bush Arm	June 21,22	June 24,25	July 7,8	
		~ 3 days	~13 days	~16 days

4.3.2 Survey Methodology

Arthropods were sampled with pitfall traps. We used 473 mL (16 oz.) clear plastic food tubs (Amcor®) as the pitfall traps (Figure 4-1), which were deployed in triangular arrays with ~1 m distance between traps. Pitfall trap cups were installed with a small trowel to a depth of approximately 10 cm so that the top rim of the cup was flush with the ground (Figure 4-1). In order to stabilize the soil around each trap, an outer cup receptacle was used. We inserted one pitfall cup inside the other and placed the trapping unit in each hole to prevent the hole from collapsing when collecting samples.

Pitfall traps were filled with ~100 mL of preservation fluid in order to kill and preserve arthropods. The type of fluid was chosen to suits the environmental conditions and frequency of trap collection (>1 day). We used propylene glycol as the preservation fluid (Prestone® LowTox Antifreeze/Coolant) because it provides excellent insect preservation and is non-toxic to wildlife that may consume the trap contents. We used a dilute solution (~25%) of propylene glycol and water. In order to obtain unbiased samples for arthropod monitoring, traps were not baited (Marshall et al. 1994).

Figure 4-1: Pitfall trap installation showing individual traps (above) set at the level of the substrate and an array of three pitfall traps (below) with cover boards installed

Pitfall traps were covered with materials found within plots, such as small pieces of wood and flat rocks (Figure 4-1) to reduce evaporation, influx of rain and debris, and catch of vertebrates. Vertebrate by-catch was recorded as an incidental observation and the specimens were collected, labelled, and preserved for identification (donated to the RBCM).

The three pitfall traps from each array were pooled as one sample unit when collected in the field. Contents from each sample unit were carefully transferred to a waterproof, plastic collection jar in the field (236 mL polypropylene snap cap specimen containers VWR®). Each sample was provided a unique collection label (one placed inside the sample jar, and labelled on the outside). The time (hh:mm) when each trap was installed and subsequently collected was recorded in order to appropriately standardize abundance of trap captures. Trap disturbance was recorded during a collection period and accounted for in catch-per-unit-effort calculations.

Preservation fluid was drained from samples in the laboratory/office shortly after field collection (≤ 2 weeks). Samples were carefully filtered with a fine mesh sieve (≤0.25 mm2), drained of preservation fluid, and transferred back into sample jars topped up with 70% ethanol for long-term preservation and storage.

4.3.3 Sampling and Replication

Terrestrial arthropods (spiders and beetles) were sampled using the methods outlined in the previous year's report (Wood et al. 2015). Methods were consistent with those described by the Resources Inventory Committee (1998d) and Biological Survey of Canada (Marshall et al. 1994). Trap arrangement and number of treatments sampled varied between reaches and are outlined as follows.

Canoe Reach

Arthropods were sampled within three study sites within Canoe Reach. In 2014 our arthropod monitoring focused on samples from Valemount Peatland North (VP-N), Packsaddle Creek North (PS-N), and Yellowjacket Creek (YJ). We intended to repeat this sampling in 2015, but unfortunately we were unable to sample arthropods from VP-N in 2015 due to a large emergence of Western Toad (*Anaxyrus boreas*) metamorphs from the woody debris removal area (treatment plot). Toads were present during both collection periods in such high numbers that the plot could not traversed or sampled by pitfall trapping. Thus, we sampled the Packsaddle Creek South (PS-S) site for arthropods in addition to PS-N and YJ in 2015.

Figure 4-2: Photo of a mass Western toad (*Anaxyrus boreas*) emergence at the Valemount Peatland North treatment area (June 16, 2015). Woody debris were removed from this area in the spring of 2015; the area has been the site of increased toad and frog breeding over the past two years (see CLBMON-58 for details)

Within each of the three sites, the three treatment areas were sampled for arthropods, including two treatments in the drawdown zone: a wood removal treatment, applied in 2014 (T= Treatment) and a woody debris accumulation control (C= Control, unaltered). An upland mature forest treatment (R= Reference) was also paired with drawdown zone treatments at each site.

In each treatment plot at three sites in Canoe Reach, nine sampling points were arranged in linear transects as detailed in Figure 4-3. Each transect was set within approximately the same elevation with transect "A" corresponding to the uppermost elevation and transect "C" corresponding to the lowest elevation. Each sampling point was comprised of an array of three pitfall traps, for a total of 27 pitfall traps deployed in each treatment plot.

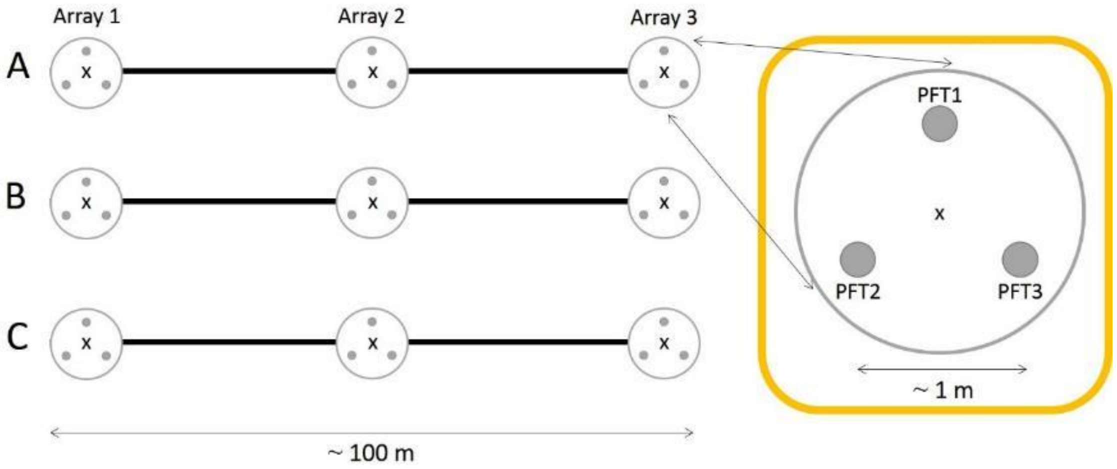

Figure 4-3: **Schematic of the experimental design used to sample ground-dwelling arthropods in each treatment at Canoe Reach.** Each treatment plot (left) contained nine individual trap arrays (right, yellow), arranged in linear transects. Pitfall arrays contained three pitfall traps (PFT; gray circles) arranged radially around a sampling station ('x'). Transects (black lines: A,B,C) were ~100 m in length with pitfall traps no closer than 1 m from each other. Transects were arranged according to elevation, such that "A" was always the uppermost transect and "C" was always the lowest transect.

Bush Arm

Arthropods were sampled within the five selected study sites at Bush Arm in 2015, including Chatter Creek (CHT), Goodfellow Creek (GDF), Hope Creek (HOPE), and two sites at Bush Arm Causeway (BAC-N and BAC-S). All sites were sampled prior to physical works trials being implemented, however, sampling occurred in delineated pre-treatment polygons. Using GIS, a treatment polygon was delineated in four of the five proposed treatment areas (not delineated at Chatter Creek prior to arthropod sampling). This polygon was replicated (copied) and placed in an area adjacent to the treatment polygon. The area selected for placement will be similar in elevation, substrate type and vegetative cover, in order to serve as a control for applied physical works treatments. The control areas will not be modified via physical works.

Further, each treatment and control polygon were overlaid with a 5-m^2 grid. Within each treatment and control polygon, five grid cells were randomly selected for sampling with pitfall traps. As in Canoe Reach, all pitfall trapping points consisted of an array of three pitfall traps, which were pooled as single functioning replicates with each treatment area of each site (n= 5 trapping arrays at each treatment in each site).

4.3.4 Taxonomy and Natural History

Spider specimens were identified to species, where possible, by a local expert (Robb Bennett, Ph.D., Research Associate at the Royal British Columbia Museum). All beetles were identified to family and individuals of the families Carabidae ("ground beetles") were identified to species. Where beetle species did not align to described species and available keys, they were assigned unique morphospecies identities that are equivalent to species-level taxon groupings. The dissection of spider and beetle specimens was necessary for many specimens in order to examination traits in genitalia and determine species identities. Beetle classification was based on numerous taxonomic works, including, but not limited to: Arnett and Thomas (2001), Campbell (1973, 1979), Goulet (1983), Lindroth (1961-1969), Pearson et al. (2006), and Smetana (1995, 1971). The entomology collection at the Royal B.C. Museum (RBCM) in Victoria, British Columbia, was used as a reference for species identifications. Spider and beetle specimens were curated according to museum standards, and a reference collection was deposited at the RBCM. Immature specimens (beetle larvae and spiderlings) were excluded for all species-level data analyses.

Species-specific natural history information was used to examine patterns in functional guilds, exotic species, etc. Spiders were classified into various feeding guilds based on their mode of prey capture (according to Cardoso et al. 2011). These classifications are included with species lists (Appendix D). Adventive (non-native) status of beetles was classified according to Bousquet et al. (2013).

4.4 Breeding Birds

4.4.1 Sampling Period

Songbirds and other breeding birds (e.g., shorebirds, grouse) were surveyed twice during the season: once in mid-June (16th to 22nd) and once in early July (3rd to 10th). During both visits surveys commenced at Canoe Reach and ended at Bush Arm, with both reaches visited during a 7 or 8 day period. Surveys began at sunrise and ended within four hours of sunrise (Ralph et al. 1995). Breeding bird surveys were conducted only during favourable conditions (i.e., no heavy wind or precipitation) to standardize surveys and minimize variability in detections due to sub-optimal environmental conditions. Surveys were consistent with Resource Inventory Standards Committee protocols (RIC 1999).The overall survey period captures the time when most migratory songbirds are on breeding territories, as opposed to surveys earlier in the year (e.g., mid-May) which often capture local breeders as well as other individuals and species that are still migrating to other locations.

4.4.2 Survey Methodology

Survey methods were changed in 2015 to improve sampling of the drawdown zone. Two related but distinct methods were used to sample breeding birds. Time-constrained, variable-radius[3] point count surveys were used to assess the diversity and relative abundance of birds in reference plots (Ralph et al. 1995). Line transects, also known as strip transects or encounter transects, were used to assess diversity and relative abundance of all birds in treatment and control plots. These two methods provide the same type of data, but are optimized for various habitats. For example, Bibby et al. 2000 state that transects are more accurate and efficient than point counts, however, “in dense habitats…point counts may be preferred” (p. 66).

---

[3] Variable in the sense that observations at varying distances from the point count centre are recorded.

For point count surveys, an observer stood stationary at a predetermined point count centre and documented all birds seen and/or heard within 75 m of the point count centre during a 6-minute count period. Furthermore, because 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).

For line transects, an observer walked a 100 m linear transect between two pre-determined start and end points and documented all birds seen and/or heard within 50 m of either side of the transect. Observers aimed to travel at a speed of 1.2 km/h, which translates into a five-minute survey for a 100 m transect.

In the sites at Canoe Reach, point count and line transects aligned with the middle transect (B) of the three pitfall trapping transects applied for arthropod sampling. However, at Bush Arm, bird surveys were conducted in a straight-line 100 m transect that was laid in the middle of the delineated treatment and control polygons, approximately parallel to the reservoir.

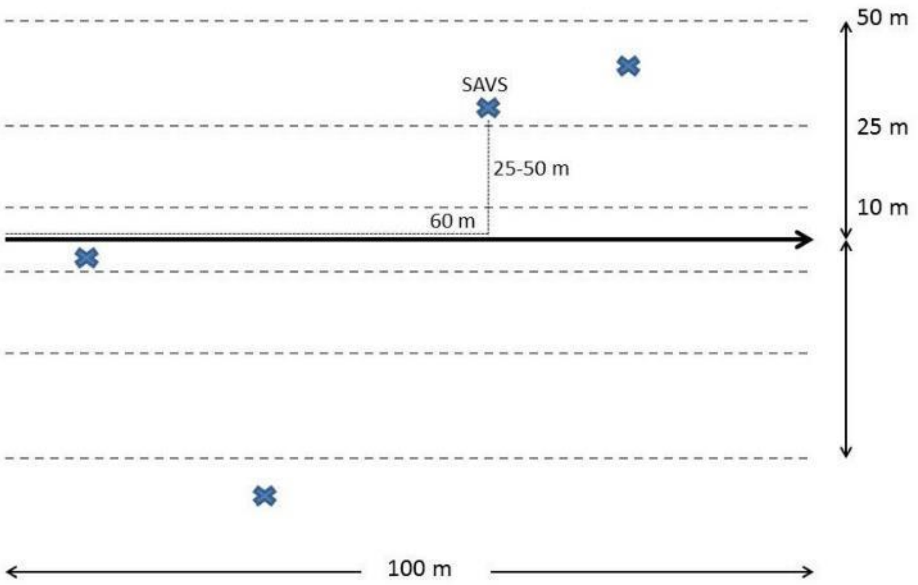

Figure 4-4: **Schematic showing the line transect sampling design. The central transect is walked from left to right for 100 m.**Birds (represented by blue “x”) are recorded from various distance bands. Here an example is given for a Savannah Sparrow (SAVS) observation. Every bird has two associated distances recorded: (1) the distance along the transect to a point perpendicular to the bird (here 60 m), and the perpendicular distance from the transect to the bird (here in the 25-50 m distance interval). Birds are recorded from both sides of the transect, with the side noted based on the observer’s direction of travel (here the sparrow is on the left)

The following data were collected at each point count station and line transect:

1. **Physical information:** site name, point count/transect 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):** species, approximate age (adult/juvenile), sex (when known), location of each bird heard or seen

within each point count plot or line transect, and detection type (call, song, or visual). Notes were made to differentiate fly-over birds from the rest of the detections; and

3. **Bird observations outside point count plots:** incidental observations of birds located outside the point count (75 m) or line transect (50 m) area at each site. These are informative for generating a robust species list for each general area but are not used in comparisons between treatments.

Nesting evidence within the control and treatment plots will provide information on the habitat-use and suitability to ground nesting and shrub nesting birds in the drawdown zone. Nest searching surveys were conducted in both reaches during the 2015 bird survey period. In all survey sites, entire control and treatment areas were traversed by surveyors and nesting evidence was recorded (species, activity, status, number of eggs/offspring). Nest searching was not performed in upland reference sites as it is not of interest to assess effectiveness of revegetation and physical works trials. Active nests were visited on subsequent surveys to check the nest status and success or failure was recorded. An increase in nesting is expected in response to successful revegetation and enhancement of drawdown zone habitats, especially within the upper elevation bands of the reservoir.

4.4.3 Sampling and Replication

In total there were 15 point counts conducted in the reference area of five sites in Canoe Reach (Table 4-2; VP-N, VP-S, PS-N, PS-S, YJ, also see Table 3-2). Line transects were surveyed in both control and treatment plots at each site (Table 4-2). Valemount Peatland South contained only one treatment transect (as no control was available at that site). As mentioned above, emergence of Western Toad metamorphs made traversing the treatment area at Valemount Peatland North impossible (Figure 4-2). Thus, we were only able to accomplish one line-transect survey for this area.

In Bush Arm, there were 12 point counts conducted in the reference area of three sites (Table 4-2; BAC-N, GDF, HOPE, also see Table 3-2). Line transects were surveyed in both control and treatment plots at each of five study sites (CHT, BAC-N, BAC-S, GDF, HOPE). As in Canoe Reach, all point counts and line transects were surveyed twice in 2015.

Table 4-2: Survey effort and type of survey conducted in Canoe Reach and Bush Arm in 2015. Note that only one survey was conducted at Valemount Peatland North, due to the high density of Western Toad metamorphs

Reach	Treatment	Survey Type	No. of Survey Stations	No. of Surveys
Canoe Reach	Reference	PC	15	30
	Treatment	Line	5	9
	Control	Line	4	8
Bush Arm	Reference	PC	12	24
	Treatment	Line	5	10
	Control	Line	5	10

As noted in previous monitoring years, treatments within the drawdown zone are not of sufficient area to adequately replicate sampling within each site. Each point count (n= 3 at each reference site) and line transect (n= 1 at each control and treatment site) are used as replicates for comparisons (sites are pooled within reach).

4.5 Incidental Observations

Throughout the study period surveyors made note of incidental observations within (or nearby) study sites. All wildlife observations, tracks, and signs of habitat use were recorded at each site. Small mammals incidentally collected during arthropod pitfall trap surveys were retained and identified to species. Wildlife observations, were summarized in tables. Cumulatively over monitoring years these incidental observations will provide presence/non-detection or checklist information for non-target taxa at each study site.

5.0 DATA ANALYSES

Patterns in focal taxon abundance, richness, and composition were assessed across treatments and sites in Canoe Reach and Bush Arm for the 2015 monitoring period. Long-term and inter-annual responses will be examined in detail in later reporting years.

5.1 Data Standardizations

Vegetation and substrate classification data were standardized to the average cover per transect. Vegetation species were totalled per transect and averaged within each treatment within sites. For arthropods, relative abundance was standardized to the number of individuals collected per trap day (CPUE). Arthropod species richness was standardized to the number of species collected per trap day.

Bird abundance was standardized to the number of observations per survey within 75 m of point count centres and 50 m on either side of line transects. Bird species richness was standardized to the number of species detected per survey, constrained by the same distance measures. The 75 m or 50 m buffer extended beyond treatment boundaries in some locations, including upland habitat within drawdown zone plots. Therefore, standardized abundance and richness measures may still overestimate the fauna of the drawdown zone.

Furthermore, as songbirds are the species being targeted in point count surveys, only songbird species, in addition to swifts and hummingbirds, are included in analyses of reference areas. Fly-overs are also excluded, with the exception of swallows, swifts and hummingbirds which are typically only detected in flight.

Bird data from reference plots are not intended to be directly compared to treatment and control transects, as the real objective is to understand the effects of treatment, and how treatment and control areas may differ over time. While the reference results (e.g., species assemblages) may be contrasted with control and treatment areas, as the same type of data is being recorded, it must be acknowledged that sampling methods and number of replicates differ, which makes the raw data not directly comparable.

5.2 Barplots and Boxplots

The average cover of substrate classes were plotted in stacked barplots in Microsoft Excel, such that the sum of each stack = 100 per cent (%) cover. These allow general assessments of the average composition of substrates in vegetation transects of the drawdown zone between treatments, sites, and years. They do not provide measures of variation, however, and thus do not inform statistical patterns in the data.

Relative abundance and relative richness of focal taxa were examined through boxplots. To aid the reader in interpreting these graphs, the following description is provided. In boxplot graphs, the boxes represent between 25 per cent and 75 per cent of the ranked data. The horizontal line inside the box is the median. The length of the boxes is their interquartile range (Sokal and Rohlf 1995). A small box indicates that most data are found around the median (small dispersion of the data). The opposite is true for a long box: the data are dispersed and not concentrated around the median. Whiskers are drawn from the top of the box to the largest observation within 1.5 interquartile range of the top, and from the bottom of the box to the smallest observation within 1.5 interquartile range of the bottom of the box. Boxplots display the differences between groups of data without making any assumptions about their underlying statistical distributions, and show their dispersion and skewness. For this reason, they are ideal in displaying ecological data. All boxplots were created using R v. 3.2.4 (R Core Team 2016).

5.3 Group Means

Results of average temperature, relative humidity, canopy cover, and vegetation cover were tabulated with group means and confidence intervals. Confidence intervals were provided for $\alpha = 0.1$ (90%) and were calculated as ±1.645 x Standard Error.

Where statistical testing was performed, differences in relative abundance and corrected richness were compared using the Kruskal-Wallis rank sum test as a non-parametric alternative to analysis of variance. Post-hoc pairwise tests were corrected for multiple comparisons with the Bonferroni adjustment ($\alpha = 0.10$ / no. of comparisons). Kruskal-Wallis tests were performed using the R agricolae package (de Mendiburu 2014).

5.4 Indicator Species

The indicator value method (Indicator Species Analysis, ISA; Dufrêne and Legendre 1997) was used to identify arthropod indicator species which can be tested overtime to measure ecological change of treatments. Indicator Species Analysis quantifies the value of each species' relationship to treatment types and sites or other categorical data. ISA is a useful method for identifying biological indicators for any combination of habitat types or sites of interest and has been routinely applied in arthropod studies (Dufrêne and Legendre 1997, McGeoch and Chown 1998; McGeoch et al. 2002).

An indicator value (IV) was calculated for each species j in each group k (for e.g., treatment type or site). IV 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 unit in a treatment or site.

The inclusion of both the specificity and fidelity of species for calculation of indicator value is an important requirement for identifying useful bioindicators. For example, high specificity alone defines "characteristic species" but without consideration of fidelity, these species may be limited in their distribution across sampling points, limiting their ability to provide information on the progress of ecological change. Useful indicators will occur reliably among sampling units belonging to a treatment type or site.

Indicator values range from zero to 1 (perfect indication). A species was considered an indicator for a given habitat when its IV differed significantly from random ($\alpha = 0.05$) after a Monte Carlo test based on 999 permutations. Dufrêne and Legendre (1997) suggested an indicator value of 0.25 to designate indicator species. For our analyses we chose a more conservative threshold level of 0.50 for designating “strong” indicator species. All ISAs were performed in the R indicspecies package (De Caceres and Legendre 2009) and only strong and significant indicator species were included in results.

Two ISAs were performed: 1) arthropod species in treatments at Canoe Reach in 2015, and 2) arthropod species in treatments in each year at Canoe Reach. Data used for ISA 1 included 151 species by 9 samples (3 Sites x 3 Treatments, pooling replicate samples and collections), which was equivalent to the community matrix used in ordination plots. Because sampling sites differed between 2014 and 2015, inter-annual comparisons required analysis using only a subset of sites that were common to each year. The data for ISA2 included only PS-N and YJ sites, pooling collections for traps within each of the 3 transects in each treatment area, such that n=3 in each Year x Site x Treatment combination.

Indicator taxa selected by these analyses may be useful for monitoring long-term changes in treatment plots. Shifts in the frequency occurrence and distribution of these indicator taxa (and the emergence of different of indicator species) in subsequent surveys will serve useful in measuring the extent of change in treatment plots as natural regeneration proceeds. For instance, the turnover in these baseline indicator species may signal alteration in the ecological characteristics of the plot (e.g., progression from a bare-ground, freshly disturbed plot with low vegetation cover, to an early seral plot with some herb and shrub regeneration).

5.5 Species Assemblages

We performed non-metric multidimensional scaling ordinations (NMDS) to determine the major compositional variation in arthropod species assemblages in 2015 (spiders and ground beetles) and to examine relationships between treatments and environmental variables. NMDS maximizes the rank-order correlation between distance measures and the distance in ordination space. Points (i.e. samples) are moved to minimize mismatch between the two kinds of distance. Any specimens that were not identified to species-level (e.g., damaged specimens) were excluded from species richness and assemblage analyses.

Community composition data frequently contain a large number of zeroes, which tends to produce highly skewed frequency distributions. Transforming abundance data is often necessary to make them suitable for ordination analyses (Legendre and Gallagher 2001). Standardized species abundances (catch-per-trap-day) were Hellinger-transformed, whereby each taxon observation was relativized by the total taxon abundance, and square root transformed (Legendre and Gallagher 2001; Legendre and Legendre 2012). Correlations between the ordination axes and environmental variables were determined with 999 permutations. The most significant variables ($p < 0.1$) and species with high weighted average scores were plotted in figures to display major patterns. NMDS analyses were performed using the vegan package (Oksanen et al. 2014) in R.

5.6 Community Similarity

Similarity in species composition across plot types and sites was calculated using the Sørensen similarity coefficient (Sørensen 1948), as follows:

% Sørensen Similarity = 2C / (A + B),

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

Venn diagrams were created using the package 'VennDiagram' in R (Chen 2015) to illustrate the number of unique species in treatment and control plots and the number of species that were shared between plots for arthropod sampling.

6.0 RESULTS

Target taxa (arthropods and breeding birds) were monitored in treatment areas at Canoe Reach and pre-treatment areas at Bush Arm in 2015. Additionally, vegetation, substrate cover, and environmental variables were recorded as they are potential important characteristics of habitat quality. Following is a results summary of the first year post-treatment responses in Canoe Reach sites and a summary of the pre-treatment condition at Bush Arm.

6.1 Environmental Conditions

6.1.1 Canoe Reach

Site-specific differences in temperature, humidity, light availability, and substrate composition may influence the vegetation and/or fauna (especially invertebrates) that occur in each treatment plot within sites. Trends in temperature and relative humidity among treatment areas appeared site specific (Table 6-1; Table 6-2). In general, drawdown zone treatments and controls were warmer and less humid than upland reference areas. The Valemount Peatland North (VP-N) site was an exception to this trend. The upland forest at VP-N is more open with dry sandy substrate and a dominant pine overstory compared to the more closed mixed-wood stands sampled at Yellowjacket Creek and Packsaddle Creek. Unfortunately canopy cover was not estimated at VP-N in 2015 due to an active toad metamorph migration, however other reference sites varied widely in their canopy closure (Table 6-3).

It is still too early to determine if microclimate has changed in the treatment plots since wood removal in 2014, however, trends in temperature and relative humidity will be explored in relation in revegetation success for the remaining years of the CLBMON-11A program.

Table 6-1: Average temperature (°C) for Canoe Reach sites in 2014 (27 June to 15 July) and 2015 (19 June to 4 July). Means given in bold with 90% confidence intervals (CI) below. T= treatment, C= control, R= reference

		2014			2015		
Site		**T**	**C**	**R**	**T**	**C**	**R**
Packsaddle Creek*	**mean**	**19.8**	**20.9**	**16.9**	**21.3**	**20.3**	**15.3**
	90% CI	0.7	0.7	0.4	0.9	0.8	0.4
Valemount Peatland North	**mean**	**19.4**	**18.4**	**20.0**	**18.2**	**17.8**	**19.4**
	90% CI	0.8	0.6	0.9	0.7	0.7	0.9
Yellowjacket Creek	**mean**	**19.3**	**17.4**	**17.2**	**18.2**	**18.5**	**16.4**
	90% CI	0.6	0.4	0.5	0.6	0.7	0.5

*exact location of data-logger differed between years by ~500 m

Table 6-2: Average relative humidity (%) for Canoe Reach sites during the sampling period for terrestrial arthropods in 2015 (19 June to 4 July). Means given in bold with 90% confidence intervals (CI) below. T= treatment, C= control, R= reference

		2014			2015		
Site		**T**	**C**	**R**	**T**	**C**	**R**
Packsaddle Creek North	**mean**	**63.2**	**55.4**	**77.2**	**65.8**	**67.5**	**93.1**
	90% CI	2.3	1.9	1.4	2.5	2.3	0.8
Valemount Peatland North	**mean**	**68.1**	**72.9**	**70.9**	**77.9**	**83.2**	**71.1**
	90% CI	2.1	1.8	2.1	1.8	1.4	2.4
Yellowjacket Creek	**mean**	**66.7**	**88.3**	**78.3**	**78.0**	**78.5**	**88.5**
	90% CI	2.0	1.1	1.7	1.8	2.0	1.2

*exact location of data-logger differed between years by ~500 m

Table 6-3: Average canopy closure (%) for Canoe Reach sites during the sampling period for terrestrial arthropods in 2015. Means are based on cover estimates at n= 3 transects within each plot. T= treatment, C= control, R= reference

		Canopy Closure (%) in 2015		
Site		**T**	**C**	**R**
Packsaddle Creek North	mean	0.0	0.0	57.3
Packsaddle Creek South	mean	0.0	5.0	56.7
Yellowjacket Creek	mean	0.0	0.0	81.7

Substrate composition was characterised within vegetation transects and varied by site and treatment (Figure 6-1). Notably, the treatment areas at the Valemount Peatland sites (VP-N and VP-S) were dominated by an organic substrate, whereas most other sites are dominated by mineral substrate. These site-specific differences in substrate composition will likely influence the effectiveness of revegetation and response to applied treatments.

As expected, woody debris distributions changed noticeably in the drawdown zone at Canoe Reach between 2014 and 2015. In particular, treatment plots at Packsaddle Creek (both PS-N and PS-S) accumulated wood since the removal treatment in 2014 (Figure 6-1). Changes in wood cover were less evident at VP-N treatment (where a log boom was installed to exclude wood debris from re-entering the treatment plot), VP-S, and Yellowjacket Creek. The resulting change in substrate composition (dominated by wood cover) between years at the Packsaddle Creek sites is illustrated in photos taken immediately post-treatment in 2014 and in June 2015 (Figure 6-2). Two out of three vegetation transects at PS-N treatment had a greater than 70% increase in cover of wood. All treatment transects at PS-S experienced an increase in wood debris from 2014 to 2015 (6.9 to 52.1% increase in wood cover). Less change in wood cover was observed for control plots (mean= 2.9% decrease in wood cover since 2014). The change in wood cover in control transects since 2014 ranged from a 17% decline at YJ to a 20.7% increase at VP-N.

The influx of wood onto cleared treatment plots (and efflux of wood from control areas) complicate our annual effectiveness monitoring of the treatments applied in the drawdown zone at Canoe Reach. Cover of wood and underlying differences in soil substrates may alter distributions of vegetation, arthropods, and other fauna. Thus, interpretation of results must consider the context of these dynamic "treatment" and "control" areas, which are prone to changes on a year-to-year basis.

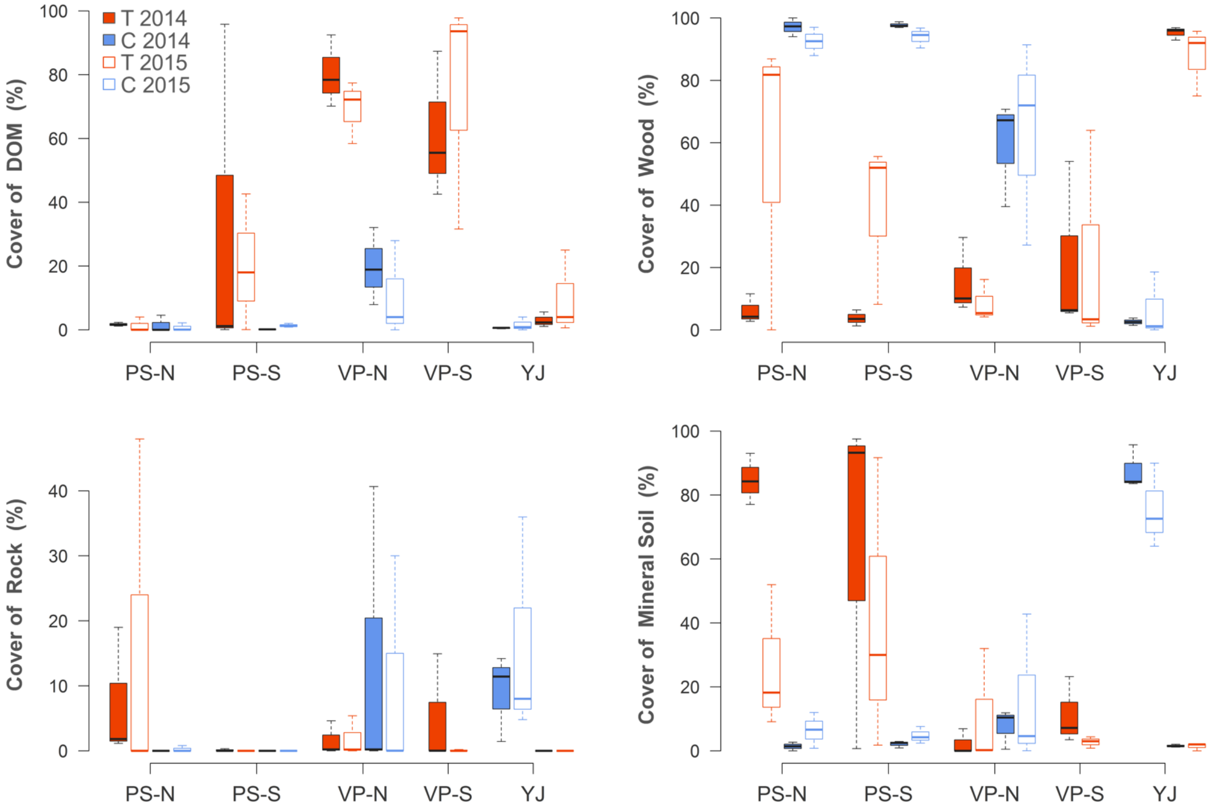

Figure 6-1: Per cent (%) cover of each substrate class recorded at treatment (T) and control (C) vegetation transect in Canoe Reach from 2014 to 2015. Site codes are as listed in Table 3-2; n= 3 transects within each treatment (wood removal)/control area. DOM= dead organic matter

PS-N Treatment 2014:

PS-N Treatment 2015:

Figure 6-2: Woody-debris removal treatment plot at Packsaddle Creek North (PS-N T) in 2014 (above, prior to vegetation sampling in 2014) and 2015 (below) looking approximately southeast (left), northwest (centre), and west towards the reservoir (right). Changes in vegetation and woody debris cover are apparent

6.1.2 Bush Arm

Environmental conditions may differ between the treatment and control areas before any treatments are applied. Thus, it is important to characterise any pre-treatment differences that may confound vegetation or wildlife responses to future treatment applications in the drawdown zone at Bush Arm. Most treatment and control areas were similar in terms of temperature and relative humidity in the drawdown zone of Bush Arm (Table 6-4). However, we did find large differences in relative humidity between control and treatment areas at the Bush Arm Causeway North (BAC-N) site. This site was more humid than nearby mature forest areas and had a milder temperature than the treatment sites at Goodfellow Creek and Hope Creek.

Table 6-4: Average temperature (°C) and Relative Humidity (%) for Bush Arm sites in 2015 (22 June to 9 July). Means given in bold with 90% confidence intervals (CI) below. T= treatment, C= control, R= reference

		Temperature			Relative Humidity		
Site		**T**	**C**	**R**	**T**	**C**	**R**
Bush Arm Causeway North	**mean**	**19.6**	**20.9**	**20.2**	**82.1**	**69.4**	**59.8**
	90% CI	0.7	0.8	0.5	1.4	2.3	1.8
Goodfellow Creek	**mean**	**23.6**	**23.7**	**19.4**	**55.6**	**55.0**	**62.7**
	90% CI	0.7	0.8	0.5	2.3	2.3	1.9

Hope Creek	**mean**	**24.0**	**24.9**	**19.2**	**53.0**	**51.0**	**71.6**
	90% CI	0.9	0.8	0.6	2.4	2.2	1.9

Most Bush Arm drawdown zone sites were completely open (canopy closure= 0), except the treatment at Hope Creek, where the presence of a cottonwood tree shaded one of the plots (Table 6-5). The reference sites were similar, providing an average of 66.7% canopy cover (min= 50%, max= 75%).

Table 6-5: Average canopy closure (%) for Bush Arm sites during the sampling period for terrestrial arthropods in 2015. Means are based on cover estimates at n= 3 transects within each plot. T= treatment, C= control, DDZ= T/C, R= reference

Site	T	C	DDZ	R
Bush Arm Causeway North	0.0	0.0	-	-
Bush Arm Causeway South	0.0	0.0	-	-
Chatter Creek	-	-	0.0	-
Goodfellow Creek	0.0	0.0	-	70.0
Hope Creek	16.7	0.0	-	63.3

There were also underlying pre-treatment differences in substrate composition. Most sites had substrates dominated by mineral soil, except at Bush Arm Causeway South, where dead organic matter comprised a large proportion of substrate cover (Figure 6-3). Wood cover also differed between treatment and control plots at some sites of Bush Arm. The BAC-S control had twice the wood cover as the treatment area at this site (T: 21% versus C: 43% wood cover). The converse was true at all other sites, where treatment transects had roughly twice the wood cover as controls. These underlying site differences in soil substrate and wood accumulation have the potential to influence the effectiveness of applied physical works treatments. Thus, substrates and wood cover will be characterised each year and changes will be assessed in relation to target taxa.

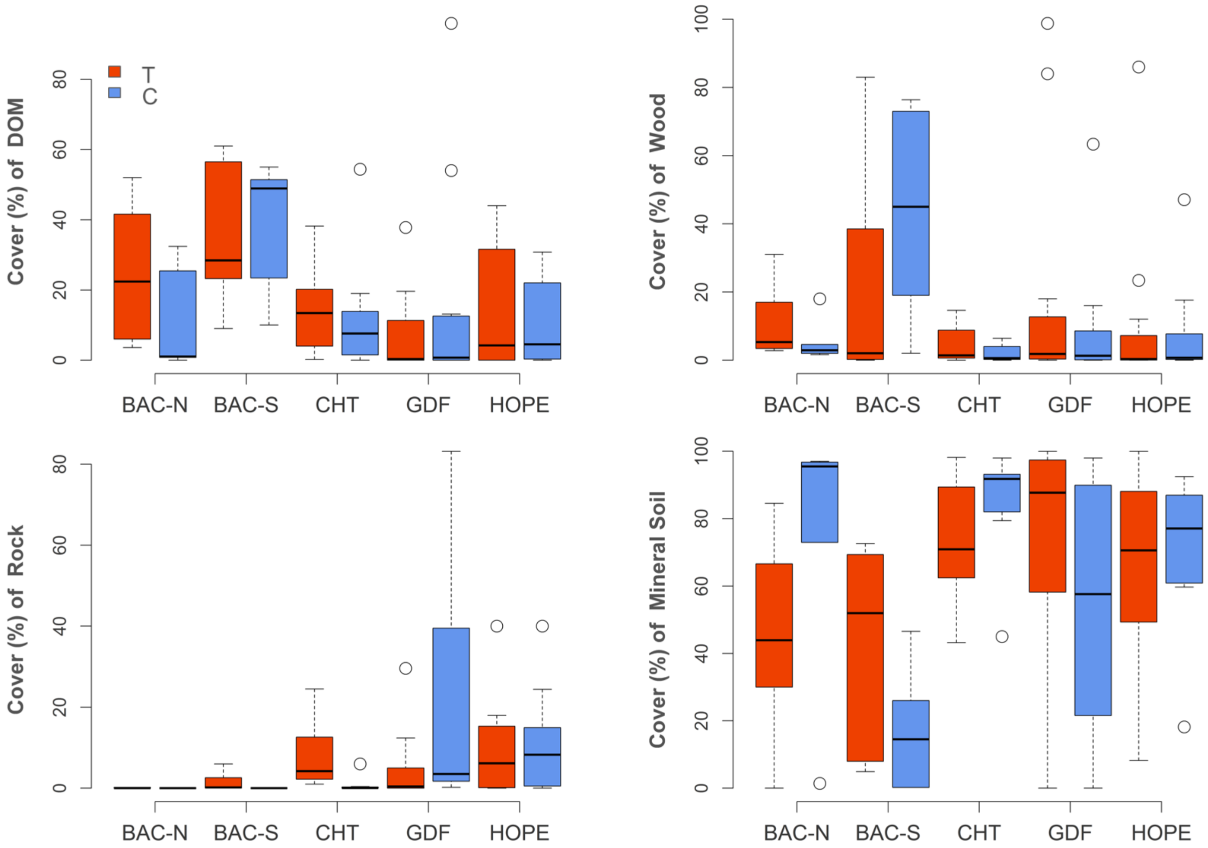

Figure 6-3: **Pre-treatment cover of each substrate class recorded in (T) and control (C) vegetation transects at Bush Arm in 2015.** Site codes are as listed in Table 3-2. DOM= dead organic matter

6.2 Vegetation

The extreme variability in vegetation cover and richness data hindered significance testing, below we provide tabulated data (means ± 90% confidence intervals) in order to summarise within and between site differences in the revegetation of the treatment areas. Results show a large amount of variation and differing patterns in vegetation between sites, supporting that each site should be considered as a case-study. Trends in vegetation cover may become clearer in future years of monitoring and will shed light on site-specific characteristics that govern the effectiveness of treatment prescriptions. Following is a general summary of patterns in the vegetation data. Detailed assessment of changes in vegetation is treated under CLBMON-9.

6.2.1 Canoe Reach

Reference transects tended towards higher herb and shrub cover than treatment or control transects (except at VP-S and YJ). Herb cover in treatment transects tended to increase since 2014 in Valemount Peatland North (from 0.5% to 5.2% herb cover) and Yellowjacket Creek (from 0.2% to 1.7% herb cover). Herb cover also appeared to increase since 2014 in controls, suggesting that increases in vegetation cover were not due to a treatment effect. There was no trend towards increased shrub cover since 2014 found for treatments. Cover of exotic vegetation tended to decline in some treatment areas between years, such as

PS-N and VP-S, but increased in other treatments (PS-S and VP-N).

Herb and shrub species richness was also variable between sites, treatments, and years (Table 6-6). There was a trend towards reduced species richness since 2014 for treatment areas at PS-N (and to a lesser extent at PS-S and VP-S). However at VP-N herb species richness increased. Herb richness did not increase in control areas at VP-N, PS-S, and YJ since 2014, but herb and shrub richness increased in the PS-N control. Shrub species richness doubled since 2014 at VP-S.

Table 6-6: Average cover and richness of herbs, shrubs, and exotic vegetation for transects (n= 3) in treatment areas at Canoe Reach sites in 2014 and 2015.

Means are given in bold with 90% confidence intervals (CI) below. T= wood removal treatment, C= control, R= reference (R only sampled in 2014). Site codes are as listed in Table 3-2

			HERBS					SHRUBS				
Vegetation Metric	**Site**		**2014**			**2015**		**2014**			**2015**	
			T	**C**	**R**	**T**	**C**	**T**	**C**	**R**	**T**	**C**
Cover	PS-N	**mean**	**3.0**	**0.0**	**24.0**	**2.4**	**0.9**	**0.0**	**0.2**	**16.4**	**0.0**	**0.7**
		90% CI	1.1	0.0	2.8	2.9	0.6	0.0	0.3	2.4	0.0	0.5
	PS-S	**mean**	**0.2**	**0.0**	**17.9**	**2.9**	**0.8**	**0.0**	**0.0**	**10.4**	**0.0**	**0.0**
		90% CI	0.1	0.0	5.7	3.9	0.8	0.0	0.0	4.5	0.0	0.0
	VP-N	**mean**	**0.5**	**3.5**	**14.0**	**5.2**	**6.2**	**0.0**	**0.1**	**30.7**	**0.0**	**0.6**
		90% CI	0.2	2.7	1.8	1.6	7.6	0.0	0.2	10.4	0.0	0.9
	VP-S	**mean**	**14.5**		**6.6**	**17.9**		**0.4**		**1.4**	**1.4**	
		90% CI	13.3		3.0	21.0		0.5		1.7	2.3	
	YJ	**mean**	**0.2**	**8.9**	**3.1**	**1.7**	**27.8**	**0.0**	**0.3**	**14.4**	**0.0**	**0.3**
		90% CI	0.0	4.4	1.5	1.2	10.7	0.0	0.3	13.9	0.0	0.4
Richness	PS-N	**mean**	**10.3**	**1.0**	**18.7**	**2.7**	**7.0**	**0.0**	**0.3**	**6.7**	**0.0**	**1.3**
		90% CI	3.6	0.9	2.0	2.0	0.9	0.0	0.5	3.6	0.0	0.5
	PS-S	**mean**	**3.3**	**2.0**	**22.0**	**2.7**	**2.0**	**0.0**	**0.0**	**5.0**	**0.0**	**0.0**
		90% CI	1.5	1.6	3.3	1.5	1.6	0.0	0.0	1.6	0.0	0.0
	VP-N	**mean**	**12.3**	**7.7**	**12.7**	**25.3**	**7.3**	**0.0**	**0.7**	**7.0**	**0.0**	**1.0**
		90% CI	6.7	5.2	2.4	4.4	4.7	0.0	0.5	2.5	0.0	1.6
	VP-S	**mean**	**9.3**		**7.0**	**8.0**		**0.7**		**5.0**	**1.3**	
		90% CI	4.8		1.6	2.8		0.5		2.8	2.2	
	YJ	**mean**	**4.0**	**6.3**	**11.0**	**7.0**	**6.0**	**0.3**	**1.3**	**6.3**	**0.3**	**1.7**
		90% CI	2.5	1.1	1.6	1.6	2.8	0.5	1.5	0.5	0.5	0.5

6.2.2 Bush Arm

There were underlying pre-treatment differences in vegetation at the Bush Arm drawdown zone sites. For example, at Goodfellow Creek (GDF) and Bush Arm Causeway South (BAC-S) herb cover was much lower in controls than treatments, prior to any physical works application (Table 6-7). Likewise, shrub cover was greater (albeit highly variable) at BAC-S control compared to the adjacent treatment polygon. Treatment transects at Hope Creek (HOPE) and Chatter Creek (CHT) exhibited greater shrub cover than controls. Exotic species were more prevalent in the treatment transects at CHT and GDF than adjacent controls.

Pre-treatment vegetation sampling also revealed some differences in species richness of herb, shrub, and exotic vegetation between sites and treatment areas (Table 6-7). For example, BAC-S control contained the highest average number of shrub species, whereas the BAC-S treatment was almost devoid of shrubs. Shrub cover was more comparable between the treatment and control area at

BAC-N, however there was a trend towards increased herb and exotic species richness in the treatment.

These differences are important to characterise prior to treatment application so that post-treatment responses can be teased apart from pre-existing site-specific phenomena. In light of the apparent site-specific nature of vegetation patterns, results should be considered individually for each site.

Table 6-7: Average cover (%) and richness of vegetation in transects of pre-treatment areas at Bush Arm in 2015. Means given in bold with 90% confidence intervals (CI) below. T= treatment, C= control

			Herbs		Shrubs		Exotics	
Metric	**Site**		**T**	**C**	**T**	**C**	**T**	**C**
Cover	**BAC-N**	**mean**	**9.0**	**11.8**	**2.5**	**3.0**	**0.1**	**0.0**
		90% CI	4.0	9.0	2.1	1.8	0.1	0.0
	BAC-S	**mean**	**8.4**	**4.8**	**1.0**	**8.6**	**0.6**	**0.7**
		90% CI	4.3	1.3	1.6	5.8	0.6	0.7
	CHT	**mean**	**11.3**	**11.2**	**0.9**	**0.0**	**1.2**	**0.3**
		90% CI	4.2	6.2	0.9	0.0	0.6	0.4
	GDF	**mean**	**5.8**	**1.7**	**0.5**	**0.1**	**1.3**	**0.3**
		90% CI	3.1	2.2	0.9	0.1	1.1	0.2
	HOPE	**mean**	**2.0**	**0.6**	**2.5**	**0.4**	**0.1**	**0.1**
		90% CI	2.1	0.2	1.8	0.5	0.1	0.1
Richness	**BAC-N**	**mean**	**14.8**	**11.8**	**1.8**	**2.3**	**2.0**	**0.8**
		90% CI	5.5	2.3	1.0	1.3	1.6	0.8
	BAC-S	**mean**	**9.7**	**9.3**	**0.7**	**2.7**	**4.5**	**2.3**
		90% CI	2.4	2.4	0.8	1.5	1.3	1.3
	CHT	**mean**	**8.7**	**5.1**	**1.3**	**0.0**	**3.7**	**1.0**
		90% CI	0.8	1.4	1.5	0.0	0.8	0.4
	GDF	**mean**	**6.3**	**3.0**	**0.6**	**0.3**	**3.0**	**1.8**
		90% CI	1.2	1.2	0.6	0.3	0.9	0.7
	HOPE	**mean**	**6.1**	**7.4**	**1.1**	**0.6**	**2.0**	**2.4**
		90% CI	1.6	2.2	0.6	0.4	0.7	0.9

6.3 Terrestrial Arthropods

Overall, 16,783 individual arthropods (6,019 spiders and 10,764 beetles) were sorted and identified from the 2015 pitfall trapping session. The abundance of beetles and spiders at Canoe Reach was more than two-fold greater in 2015 than for 2014 pitfall trap samples (with equal replication). Spiderlings and beetle larvae were excluded from data used in abundance patterns, leaving 2,146 adult spiders and 10,158 adult beetles for use in 2015 data analyses. A summary of abundance is provided in Table 6-8.

Over the past two years, we have documented 17 distinct families of spiders. Most spiders were in the family Lycosidae – Wolf spiders (54% by abundance), followed by the family Linyphiidae – Sheetweb and dwarf spiders (27%). Beetles have been classified into 39 distinct families. Most beetles were in the family Carabidae – Ground beetles (46%), followed by the family Staphylinidae – Rove beetles (33%).

Table 6-8: Total spider (Araneae) and beetle (Coleoptera) abundance collected in 2014 and 2015 pitfall trap surveys

			Abundance (No. of Individuals)		
Year	**Reach**	**Stage**	**Araneae**	**Coleoptera**	**Total**
2014	Canoe Reach	All	2773	3559	6332
		Adult	2168	3449	5617
2015	Canoe Reach	All	4974	8759	13733
		Adult	1727	8200	9927
2015	Bush Arm	All	1045	2005	3050
		Adult	419	1958	2377
Grand Total		Adult	4314	13607	17921
		All	**8792**	**14323**	**23115**

6.3.1 Canoe Reach

Relative Abundance and Species Richness

The relative abundance (CPUE) of arthropods was greatest in reference plots in all years and both reaches of Kinbasket Reservoir (Table 10-1). In general, spider abundance was lower in wood removal treatments in each site (Figure 6-4). This trend in low abundance was not consistent for beetles across sites. For e.g., standardized beetle catch was greater in the treatment at VP-N than reference or control areas. Exotic beetles were more abundant in treatment plots than in control or reference plots, which is consistent with the results of 2014 (Figure 10-2; e.g., *Pterostichus melanarius* [Illiger], *Harpalus affinis* [Schrank], *Bembidion tetracolum* Say). Relative abundance of exotic beetles declined in the Yellowjacket Creek treatment from 2014 to 2015.

A total of 151 arthropod species were identified from Canoe Reach samples in 2015: 100 spider species and 51 ground beetle species. Richness was variable between sites, treatments, and years (Figure 6-5). The most consistent trend was for greater spider richness in reference traps within each site in each year. Ground beetle richness was also greatest in reference traps in each site sampled in 2015, but was variable for sites sampled in 2014.

Ground-hunting spiders, such as Wolf spiders, were much more abundant in the drawdown zone (control and treatment) than in reference sites (Figure 6-6). Conversely, Space-web and Sheet-web weaving spiders were more abundant at higher elevations in the upland reference sites. The lack of web-building spiders in the drawdown zone is likely due to their requirements for vegetation structure.

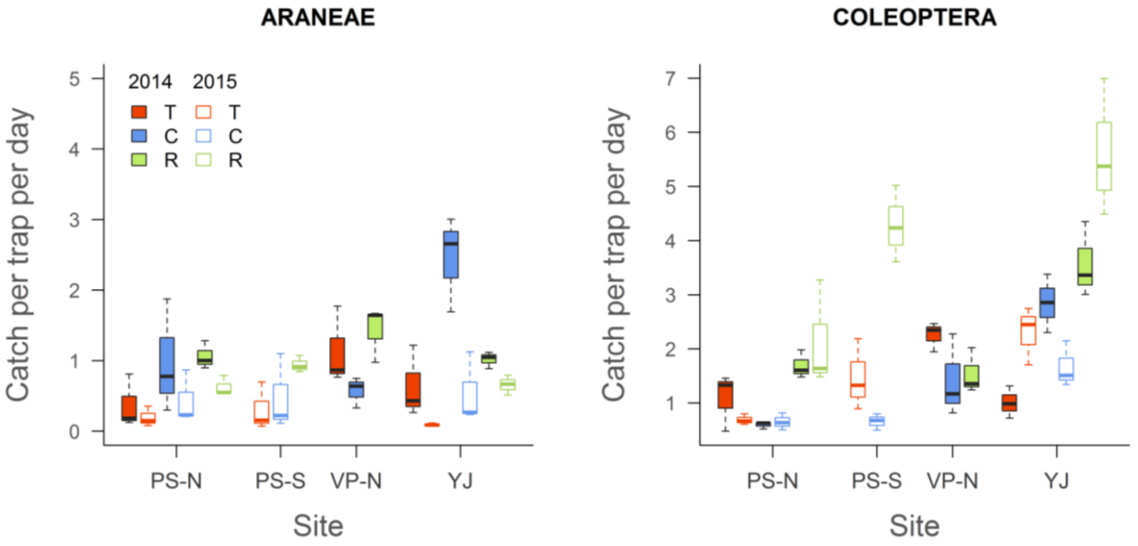

Figure 6-4: **Relative abundance (Adult catch per trap-day) of spiders (left) and beetles (right) across treatment types and sites at Canoe Reach.** Both 2014 (filled boxes) and 2015 (white boxes) monitoring years are shown, with data pooled at the transect level (n=3). PS-N = Packsaddle North, PS-S = Packsaddle South, VP-N = Valemount Peatland North, YJ = Yellowjacket Creek

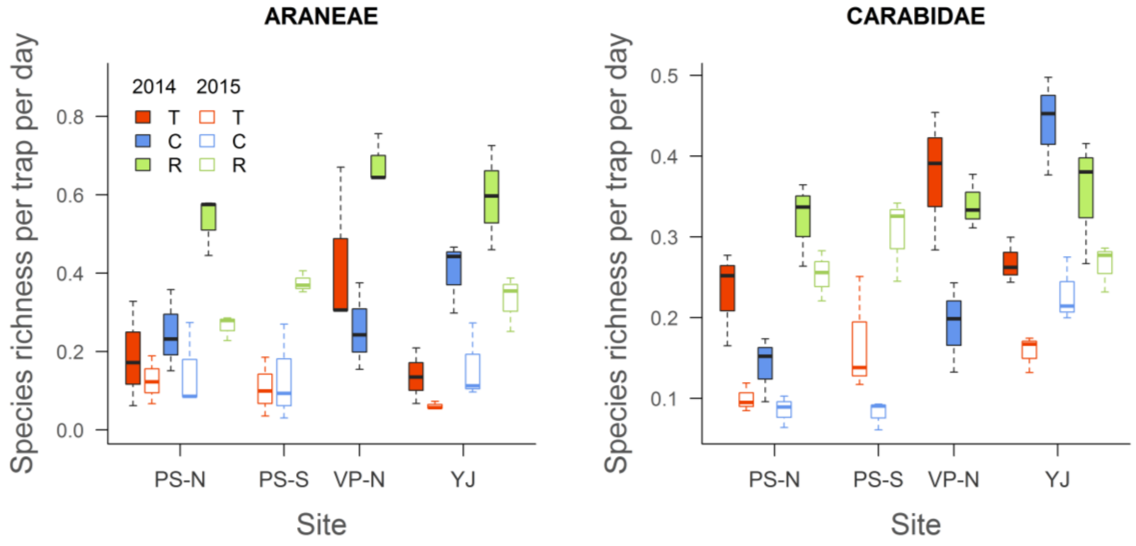

Figure 6-5: **Corrected species richness (species per trap per day) of spiders (left) and ground beetles (right) across treatment types and sites at Canoe Reach in 2014 and 2015.** Abbreviations and colors as above

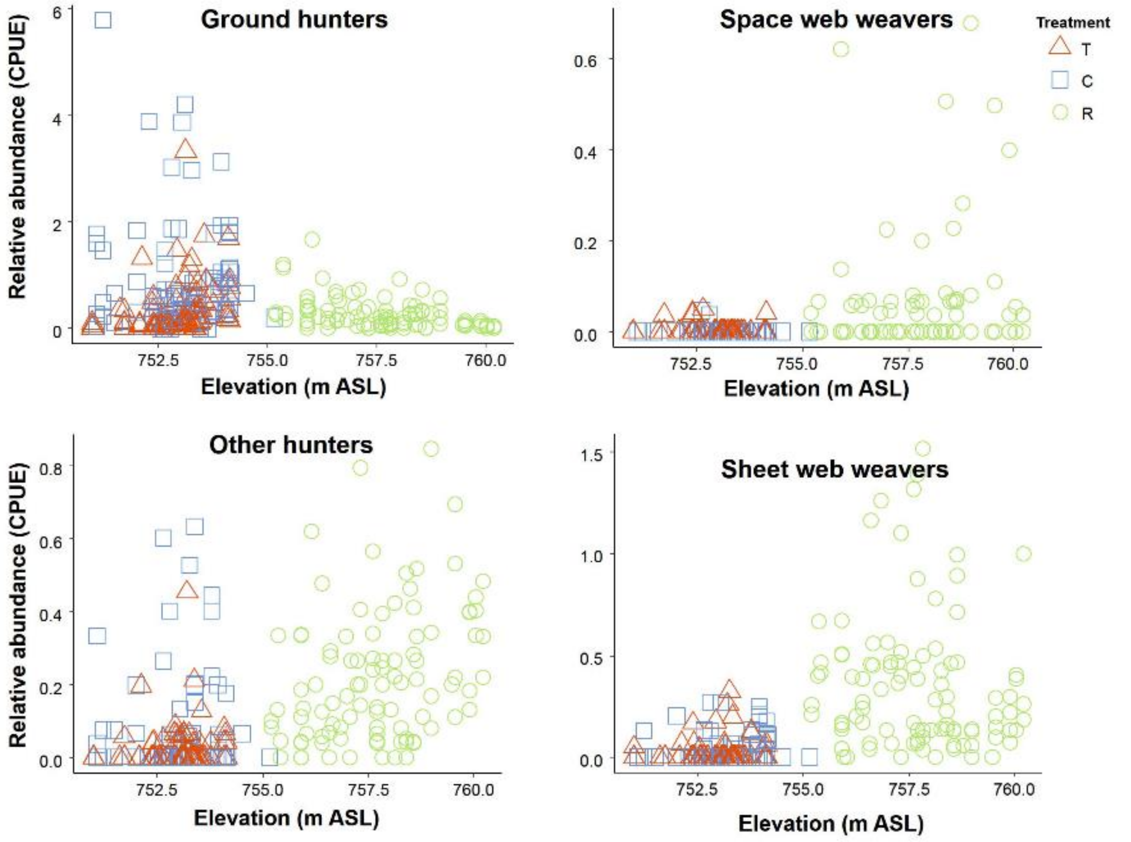

Figure 6-6: **Relative abundance of four functional guilds of spiders by treatment and elevation at Canoe Reach.** Data is from 2014 and 2015 (all sites combined). CPUE= catch-per-unit-effort= spiders per trap per day. Two guilds were excluded due to low frequency and catch (Ambush hunters and Orb weavers)

Indicator Species

Indicator Species Analysis (ISA) selected 27 arthropod species as indicators of one or more treatment type. The ground spider *Drassodes neglectus* and the ground beetle *Amara littoralis* were characteristic of wood removal treatment plots (Table 10-2; Figure 10-3). Both are commonly found in non-forested habitats (Cárcamo et al. 2014; Larochelle and Larivière 2003). No characteristic species were found for control plots in the 2015 Canoe Reach sample, though five species were associated with both the treatment and control plots, suggesting that they are drawdown zone generalists (Figure 10-4).

Sixteen species were strongly associated with reference sites (Table 10-2). These species include forest specialists (e.g., *Pterostichus herculaneus* and *Scaphinotus angusticollis*). *Scaphinotus angusticollis* feeds mostly on snails and slugs (also earthworms and spiders) and requires moist rotten logs and tree stump for shelter during the day and overwintering (Larochelle and Larivière 2003). *Pterostichus herculaneus* is found mostly in shaded, mixed or coniferous forests and also shelters during the day under logs and loose bark of trees (Larochelle and Larivière 2003). Additionally, both *P. herculaneus* and *S. angusticollis* are not capable of flight. These species have reduced (or absent) wings with fused wing covers. They are very capable ground runners, but the lack of flight ability may disadvantage them in habitats that are ephemeral (such as the drawdown zone).

Arthropod Assemblages and Similarity

Arthropod species assemblages were clearly distinct among treatment types in 2015 (Figure 6-7, left). Wood removal treatment sites were most dissimilar from forested references, thus occurring more distant in ordination space (only 35.6% similar in species composition, calculated as Sørensen Similarity). Control plots had 45.3% of their species in common with reference plots and 52% of their species in common with adjacent wood removal treatments (Figure 6-8).

Several environmental vectors were significantly related to the axes of the ordination of arthropod assemblages in each treatment (Figure 6-7, right). Reference plots had higher canopy cover, relative humidity, leaf litter, and moss cover. Treatments had greater cover of bare ground, rocks, mineral soil, and higher mean daily temperature. Coarse woody debris and fine woody debris cover was not significantly related to ordination axes.

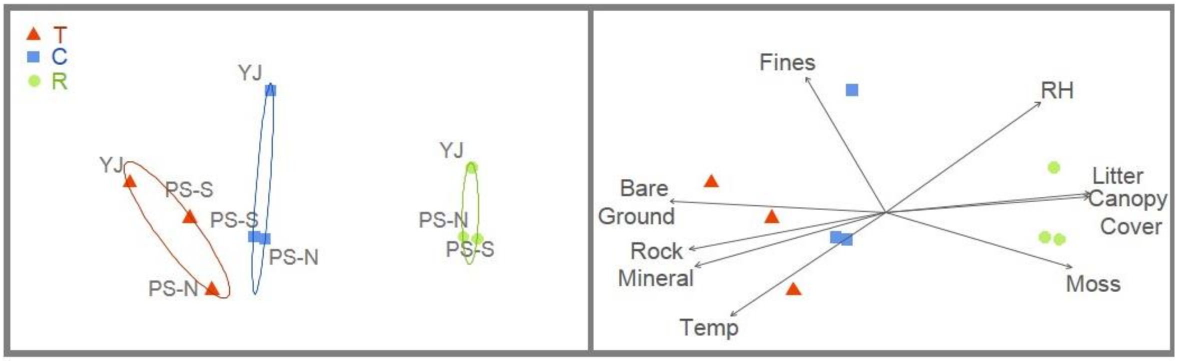

Figure 6-7: Non-metric Multidimensional Scaling (NMDS) ordination diagram of spider and ground beetle species assemblages from treatment types at each site in Canoe Reach in 2015. Left: assemblages in each treatment type delineated by 90% confidence ellipses. Right: environmental vectors significantly ($p<0.1$) related to the ordination axes (direction and length relative to the association). RH = Relative Humidity, Temp = Temperature, and per cent cover of substrate classes are shown

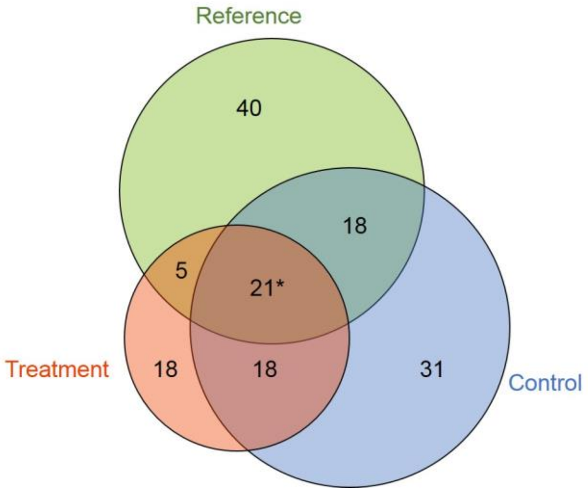

Figure 6-8: **Venn diagram showing the number of arthropod species unique to each treatment type, and number of species shared between treatment types for year 2015 at Canoe Reach.** Area of each circle is proportional to the number of species, where treatment= 62 spp., control= 88 spp., and reference= 84 spp. *number of species shared by all treatment types (overlap between circles is approximate)

6.3.2 Bush Arm

Relative Abundance and Species Richness

Underlying pre-treatment differences in the beetles at BAC-S were found, where the treatment area had higher abundance of all beetles (Figure 6-9), higher abundance of ground beetles (Figure 10-5), and higher richness of ground beetles (Figure 6-10) relative to the adjacent control. This mirrors the trends discussed for vegetation, where shrub cover and richness differed between the BAC-S pre-treatment drawdown zone plots. It will be important consider these underlying differences when evaluating the effectiveness of physical works trials at BAC-S, since beetle abundance and richness are inherently different before the treatment application. Abundance and richness of spiders did not seem to differ between pre-treatment drawdown zone plots at each site (Figure 6-9; Figure 6-10).

The two reference sites (Goodfellow Creek and Hope Creek) had more spiders and beetles than the pre-treatment drawdown zone plots at those sites (Figure 6-9). Spider richness was greatest in the reference traps at GDF and HOPE, whereas ground beetle richness was greatest in the BAC-N drawdown zone traps.

Adventive ground beetles were absent from most study sites in Bush Arm in 2015 (Figure 10-6), except for the BAC-N control and treatment and BAC-S treatment. Greater abundance of introduced ground beetle species at these sites is likely due to the causeway having heavier exposure to vehicles, human use, and proximity to the road, relative to the other study sites.

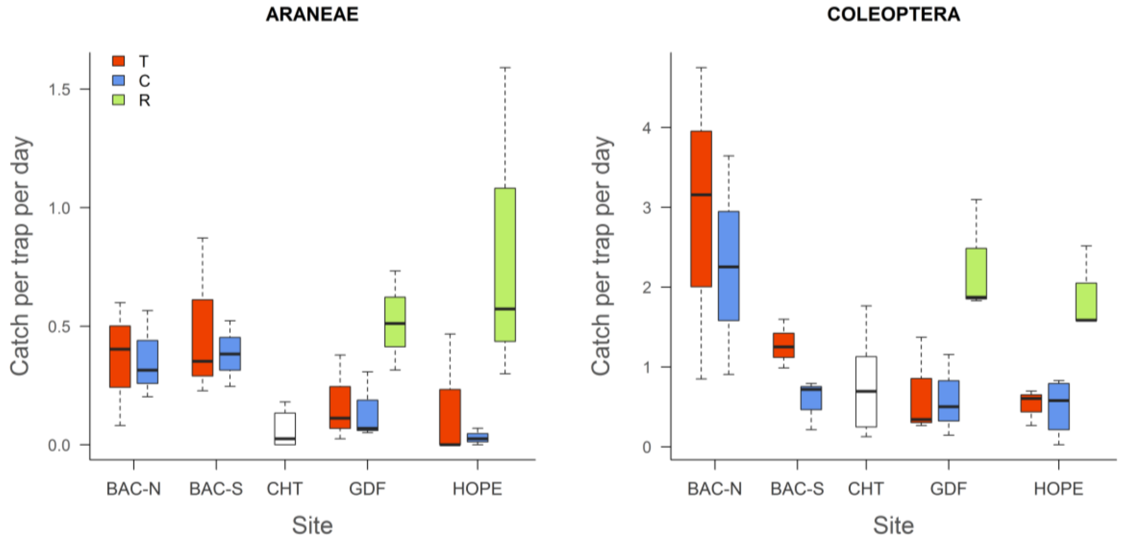

Figure 6-9: Relative abundance (Adult catch per trap-day) of spiders (left) and beetles (right) across pre-treatment polygons and sites at Bush Arm. Data pooled at the trap level (2 collections of 3 traps in each treatment in each site). Abundance includes all specimens collected. Chatter Creek (CHT, white) was not sampled in defined pre-treatment/control areas. BAC-N = Causeway North, BAC-S = Causeway South, GDF = Goodfellow Creek, HOPE = Hope Creek (note: unequal scaling of y-axes)

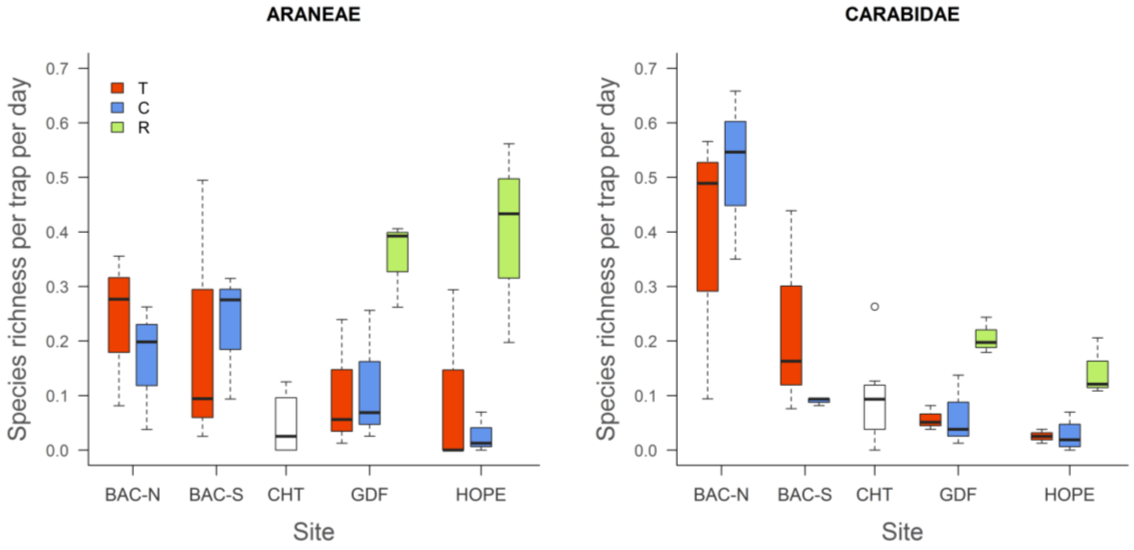

Figure 6-10: Corrected species richness (species per trap per day) of spiders (left) and ground beetles (right) across treatment types and sites at Canoe Reach in 2014 and 2015. Data pooled at the trap level (2 collections of 3 traps in each treatment in each site). Abundance includes all specimens collected. Chatter Creek (CHT, white) was not sampled in defined pre-treatment/control areas. BAC-N = Causeway North, BAC-S = Causeway South, GDF = Goodfellow Creek, HOPE = Hope Creek

Arthropod Assemblages & Similarity

Arthropod species assemblages did not differ between pre-treatment drawdown zone control and treatment areas at Bush Arm in 2015 (Figure 6-11). Treatment and control sites had 64% of their species in common (Figure 6-12). However, the drawdown zone had only 25.5% to 28.3% of arthropod species in common with the upland reference sites (control and treatment, respectively; calculated as Sørensen Similarity). Variation in arthropod communities could be due to substrate differences among sites. For e.g., the control area at Hope Creek was especially rocky, being comprised of gravel and cobbles, whereas the Bush Arm Causeway North area was dominated by clay and silt mineral soils, and reference sites were characterised by high moss and leaf litter cover.

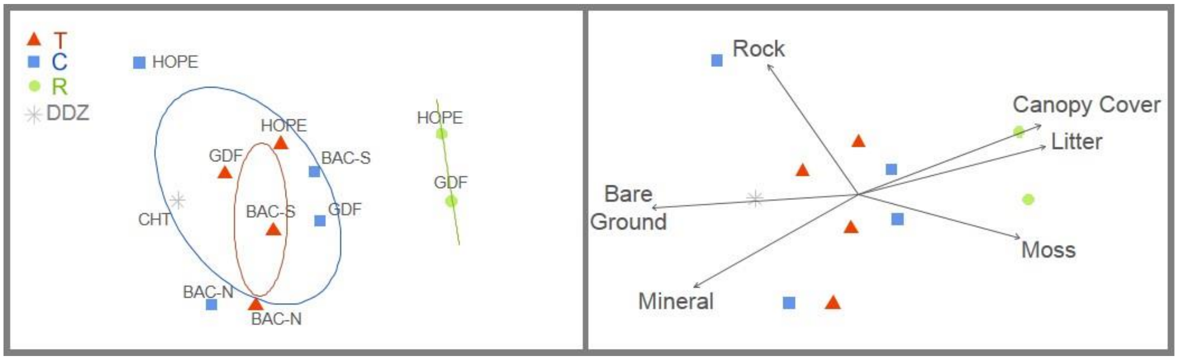

Figure 6-11: **Non-metric Multidimensional Scaling (NMDS) ordination of spider and ground beetle species (Araneae and Carabidae) assemblages within each pre-treatment type at Bush Arm in 2015.** Left: assemblages in each treatment type delineated by 90% confidence ellipses. Right: environmental vectors significantly (p<0.1) related to the ordination axes (direction and length relative to the association)

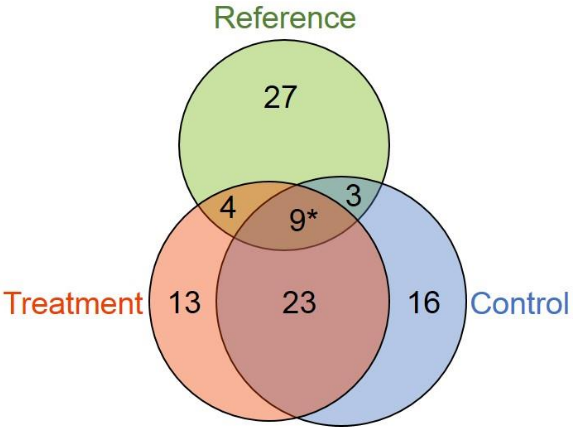

Figure 6-12: **Venn diagram showing the number of arthropod species unique to pre-treatment plots and number of species shared among pre-treatment plots sampled during 2015 at Bush Arm.** Area of each circle is proportional to the total number of species, where treatment= 49 spp., control= 51 spp., and reference= 43 spp. *number of species shared by all treatment types (overlap between circles is approximate)

6.4 Breeding Birds

A total of 57 species were recorded from all surveys in both reaches, within/near the reference, treatment and control plots in 2015 (Table 6-9; no constraint on distance or bird group). During point count surveys in upland forests 52 species representing 558 individuals were recorded at all distances from point count centres. Treatment and control plots together accounted for 36 species and 146 individuals at all distances from line transects (Table 6-9).

Only two species of conservation concern were located during these surveys: five observations totalling fifteen Barn Swallows (*Hirundo rustica*) and one individual Bank Swallow (*Riparia riparia*). Both swallows are designated Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and the Barn Swallow is blue-listed in British Columbia. The Barn Swallows were observed on two dates at both the northern and southern ends of the Bush Arm Causeway, and the Bank Swallow was detected flying over the southern end of the causeway at Bush Arm.

Table 6-9: Total number of species (Spp), observations (Obs) and individuals (Ind) of all bird species recorded at all distances during breeding bird point count and line transect surveys in 2015. Both reaches are combined, with pre-treatment, treatment, and control plots pooled in the "drawdown zone" category. Includes birds not located within the plot boundaries

Species Group	Reference			Drawdown Zone			Total		
	Spp	Obs[1]	Ind[2]	Spp	Obs	Ind	Spp	Obs	Ind
Hawks, Eagles, Falcons and Allies				1	2	2	1	2	2
Kingfishers and Allies	1	1	1				1	1	1
Loons	1	1	1	1	1	2	1	2	3
Upland Game Birds	1	1	1				1	1	1
Shorebirds, Gulls, Auks & Allies	3	7	8	3	20	21	4	27	29
Songbirds	41	496	527	28	98	117	44	594	644
Swifts and Hummingbirds	1	2	2	1	2	2	1	4	4
Waterfowl	1	3	3	1	1	2	1	4	5
Woodpeckers	3	14	15				3	14	15
Total	**52**	**525**	**558**	**35**	**124**	**146**	**57**	**649**	**704**

Considering the criteria used to constrain both the point count and line transect data, there were four species represented by a single sighting. Conversely, the top ten most detected species (27.0 per cent of species) accounted for 66.0 per cent of all detections. These commonly detected species were from multiple families and genera, with the top five most detected species belonging to four different passerine families (Tyrannidae, Turdidae, Vireonidae, Parulidae).

Ten species were recorded in all three treatment types (i.e., control, treatment, and reference). These include six of the ten most commonly detected species. However, for many of these species, the bulk of detections occurred in the reference areas (for example, though Warbling Vireo was detected in all three treatment types, 31 of 36 observations were in reference habitats; Figure 6-13). Eleven species were recorded from two treatment types, and 16 species were unique to a single treatment type. Of the 16 species found solely in one treatment type, 15 were in reference habitats, while the remaining one was in a control.

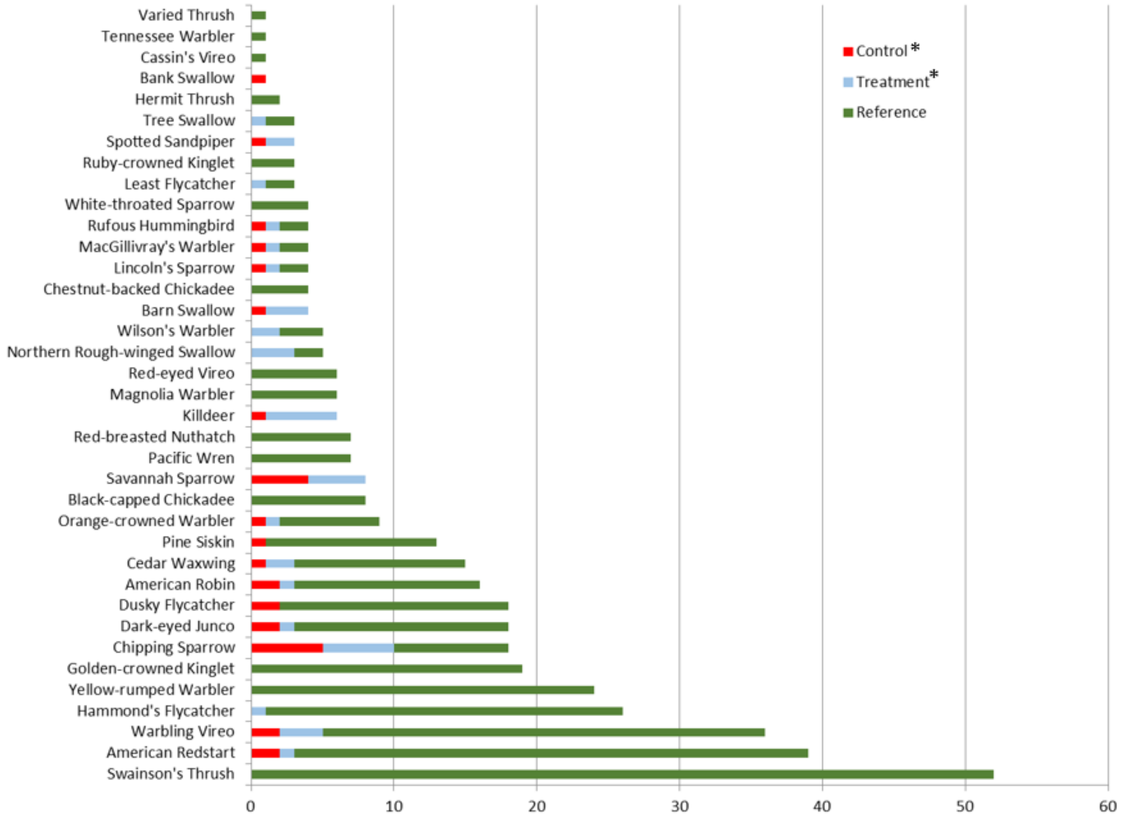

Figure 6-13: Number of constrained observations of each species recorded by treatment in 2015 (detection distance limited to 50 m). *Note: both Bush Arm pre-treatment data and Canoe Reach post-treatment data are pooled in this graph; it should not be used to infer treatment differences

At Canoe Reach during the 2015 monitoring session birds were surveyed one-year post wood debris removal (three years after removal at VP-S). Three treatments were assessed: upland references, drawdown zone wood removal treatments, and adjacent drawdown zone wood accumulation controls. Although treatment sites had been cleared of woody debris in prior years, some of these treatment plots received input of wood loads during the previous inundation period between debris removal in 2014 and songbird surveys in 2015, potentially confounding or obscuring results.

At Bush Arm, birds were surveyed in upland reference, and drawdown zone pre-treatment, and control areas (designated as "treatment" and "control"). Although treatment and control areas were specified, these were all pre-treatment surveys as no physical works trials occurred at Bush Arm prior to surveys. In total there were twelve point counts conducted in the reference area of four sites in Bush Arm. Both a control and treatment transect were sampled from five sites in Bush Arm, for a total of ten transects. Reference areas were surveyed in three of these sites (Bush Arm Causeway North, Goodfellow Creek, and Hope Creek).

6.4.1 Canoe Reach

We found no difference between controls and treatments in their standardized abundance and standardized species richness in 2015 (Table 6-10). No differences in bird richness or abundance were apparent in boxplots of treatment and control transects (Figure 6-14). Control transects yielded a total of 17 observations (21 individuals) of 11 species, compared to 19 observations (19 individuals) of 13 species in treatments (Table 6-10; Figure 6-15). As noted earlier, the low number of detections in the drawdown zone creates a problem of sparse data where differences may be due to chance. It is not clear whether species composition varied based on within-site differences between control and treatment areas or due to random encounter events. Thus, additional years of data collection are required before firm conclusions can be drawn.

Table 6-10: Standardized abundance and standardized number of bird species detected at survey stations in Canoe Reach in 2015. Data are constrained to include only birds within 75 m of point count stations or 50 m of line transects

Treatment	Survey Type	No. of Surveys	No. of Spp	No. of Obs.	Spp/ Survey	Obs/ Survey
Reference	PC	30	27	178	0.9	5.9
Treatment	Line	9	13	19	1.4	2.1
Control	Line	8	11	17	1.4	2.1

Reference sites had a greater diversity and abundance of birds than drawdown zone plots. Most (all but three) of the species found in drawdown zone plots were also found in upland reference sites. These shared species are those which typify edge habitats (e.g., shrubby areas along ecotones). It is the structural complexity and diversity creating a large number of niches that likely account for the greater diversity of birds in reference relative to treatment and controls. This is especially true of passerines (songbirds), which comprise the largest bird family. While open habitats of the drawdown zone may be favoured by other bird families (i.e., shorebirds, waterfowl), these groups contribute a relatively small amount to overall breeding bird richness in the region. Thus, the majority of species detected in controls and treatments utilize shrubby or forested habitat for nesting and do not likely breed in the drawdown zone, though they may be using those habitats for foraging or singing perches.

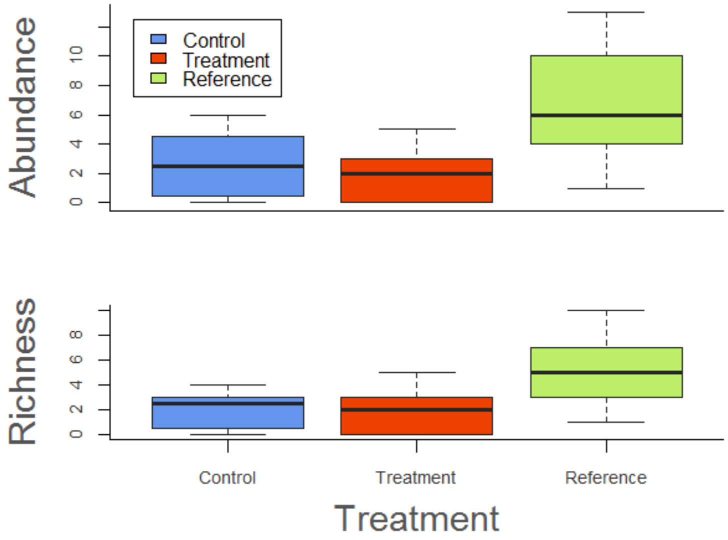

Figure 6-14: Boxplots of relative abundance (number of individuals per survey; top panel) and richness (number of species per survey; bottom panel) at each treatment type in Canoe Reach in 2015

Three species were unique to control and treatment transects in Canoe Reach: Spotted Sandpiper, Rufous Hummingbird, and Savannah Sparrow. The Spotted Sandpiper was the only non-passerine detected during line transect surveys at these sites. Although Savannah Sparrow was only detected in control line transects, this species was found to breed in treatment areas during our nest searches (Table 6-11). As treatment sites revegetate, it is expected that Savannah Sparrow abundance will increase in those areas.

Spotted Sandpiper was only detected during line transect surveys in treatment plots, and consistently, nests of this species have only been detected in treatment areas at Canoe Reach. Spotted Sandpipers may be responding to habitat opened up in treatments due to the woody debris removal as they are characterised as a pioneering species that quickly and frequently colonizes new sites (Ehrlich et al. 1988). Both Spotted Sandpiper and Savannah Sparrow are known to breed in the drawdown zone at Canoe Reach, and further surveys and nest searches will inform whether they are associated with particular treatments. The response of these two species in particular will continue to be monitored as they may be useful as indicators of revegetation success.

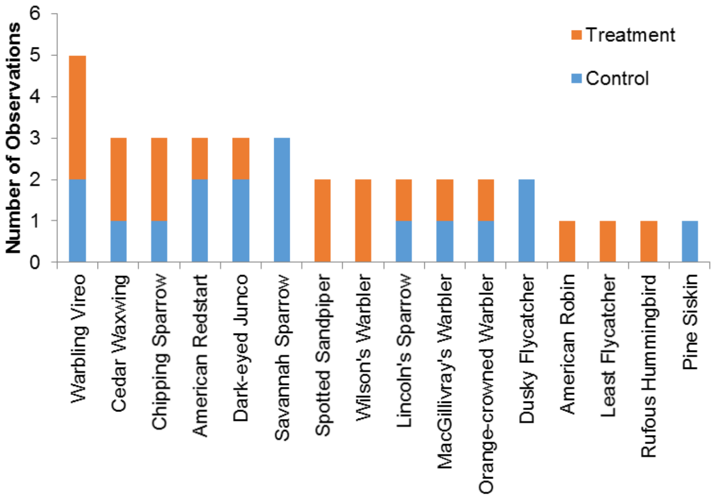

Figure 6-15: Number of observations per species recorded in treatment (orange) and control (blue) transects in Canoe Reach in 2015 (data constrained by distance)

Reference point count surveys resulted in 178 observations of 27 species (190 individuals) that were detected in reference sites (Figure 6-16; data constrained to within 75 m and by species group). Based on the constrained songbird data, species composition varied markedly between reference sites from only 31.6% similarity to 69% similarity (mean Sørensen Similarity= 53.1%). Reference sites housed 13.4 species per site on average. Approximately half of all species detected in the reference sites of Canoe Reach (14 of 27) were unique to the reference treatment, including several of the most frequently detected species (Figure 6-16). Most of the species detected in references are typical of forested landscapes, with individual species showing varying preferences for forest structure, tree composition, canopy closure, etc., which may explain the between site differences in species composition.

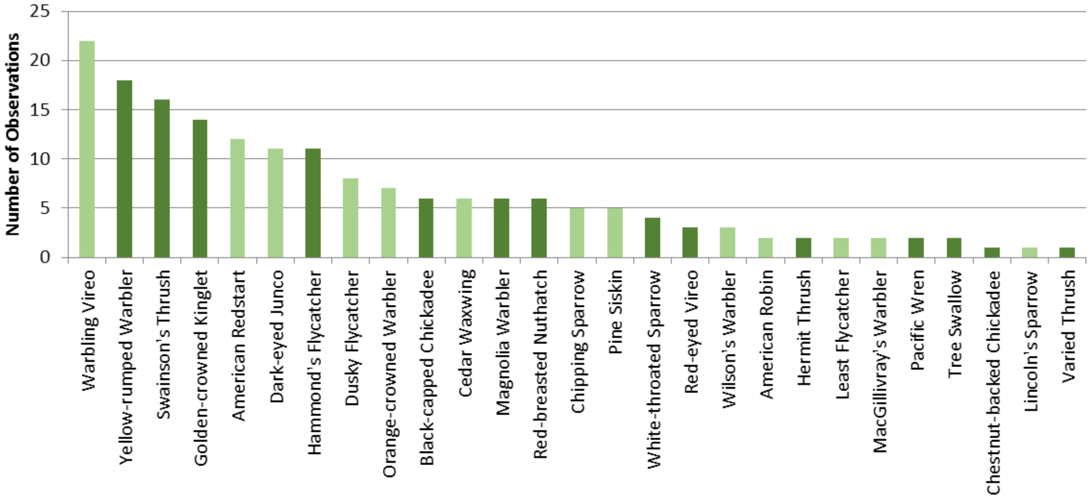

Figure 6-16: **Number of observations per species recorded in reference plots in Canoe Reach in 2015.** Dark green bars indicate species unique to reference plots (i.e., not detected in drawdown zone surveys)

Nesting Evidence

Treatment and Control plots were nest-searched over the same period as line transect surveys (reference areas not surveyed for nests). Four nests were found at Canoe Reach drawdown zone sites between June 16th to 18th, and three other evidences of nesting (i.e., recently fledged flightless young) were discovered on July 5th (Table 6-11). The nests were all located in treatment plots or in the peatland area outside of formal plot boundaries. As shorebird young are precocial, flightless, and typically leave the nest within 24 hours of hatching, their presence indicates nesting in the vicinity, but the exact location of their nest and which treatment type they nested in cannot be known with certainty.

Table 6-11: **Details of bird nests located in Canoe Reach in 2015 (site codes provided in Table 3-2).** N/A= not applicable (outside of treatment polygon)

Site	Species	Date Found	Nest Substrate	Treatment Type	Nest Fate
PS-N	Chipping Sparrow	16 June	Shrub	Treatment	Probable Success
VP-N	Savannah Sparrow	17-June	Ground	Treatment	Probable Success
VP-N	Killdeer	5-July	Ground	N/A	Success
VP-N	Savannah Sparrow	18-June	Ground	N/A (Lower peatland)	Unknown
VP-N	Savannah Sparrow	18-June	Ground	N/A (Lower peatland)	Unknown
VP-S	Spotted Sandpiper	5-July	Ground	N/A	Success
YJ	Spotted Sandpiper	5-July	Ground	N/A	Success

As expected based on the available habitat in treatments, most nests were located on the ground. One Savannah Sparrow nest was located 0.5 m up in a 1.5 m tall willow (*Salix* spp.) that was otherwise in the open at the edge of the drawdown zone. Two nests were located in the peatlands near Valemount Peatlands North, but outside of designated control or treatment plots. This is an area with higher Savannah Sparrow density and the response of treatments in areas with adjacent source populations of drawdown-zone species may be easier to detect than areas without adjacent suitable breeding bird habitat. The Spotted Sandpiper nest at Yellowjacket Creek was similarly outside of either treatment or control plot boundaries, but was situated within the drawdown zone in proximity to both plot types.

Out of the four physical nests found, three were found while the adults were incubating eggs, and one while the young were still in the nest. Two of the nests (both Savannah Sparrows in the peatland) were not visited again and the nest fate is unknown, but four eggs or young were present in the two nests respectively at the time of their discovery. The other two nests (one Chipping Sparrow and one Savannah Sparrow) both probably fledged four young; though that Savannah Sparrow nest had five eggs when discovered, only four eggs hatched, and the fifth egg was still present in the nest with evidence (feces) that the other four had likely fledged.

The three shorebird nests consisting of recently fledged young, indicates successful nesting by Killdeer and Spotted Sandpipers in the drawdown zone. Both of these species are known to nest in open habitats, not far from water. These species forage primarily on flying insects, thus nesting may be related to density of arthropod prey in the local control and treatment plots. Shorebird nests and nesting attempts in control or treatment plots will be examined in the future, especially as woody debris removal creates additional nesting opportunities for these species in the drawdown zone.

6.4.2 Bush Arm

Control plots yielded 11 observations (15 individuals) of seven species, and treatment plots had 20 observations (24 individuals) of seven species (Table 6-12; Figure 6-18; data constrained by distance). Standardized number of species was equivalent between control and treatment plots, which is expected for pre-treatment sampling where no underlying differences between control and treatment plots exist. However, the number of observations per survey in treatments were almost twice that of controls (Table 6-12), perhaps suggesting some differences in bird density between pre-treatment plots. Boxplots showed some variation in bird abundance and richness between drawdown zone plots (control and treatment transects) (Figure 6-17). However, no significant differences were detected in rank mean abundance or rank mean richness between drawdown zone transects (control and treatment transects) (Kruskal-Wallis tests; p> 0.1). Reference counts had greater bird abundance and richness than drawdown zone plots.

Table 6-12: Standardized observations and standardized number of species detected at survey stations in Bush Arm in 2015. Species and observations are reported from within 75 m of point count surveys or 50 m of line transects

Treatment	Survey Type	No. Surveys	No. Spp	No. Obs.	No. Spp/Survey	No. Obs/Survey
Reference	PC	24	24	164	1.0	6.8
Treatment	Line	10	7	20	0.7	2
Control	Line	10	7	11	0.7	1.1

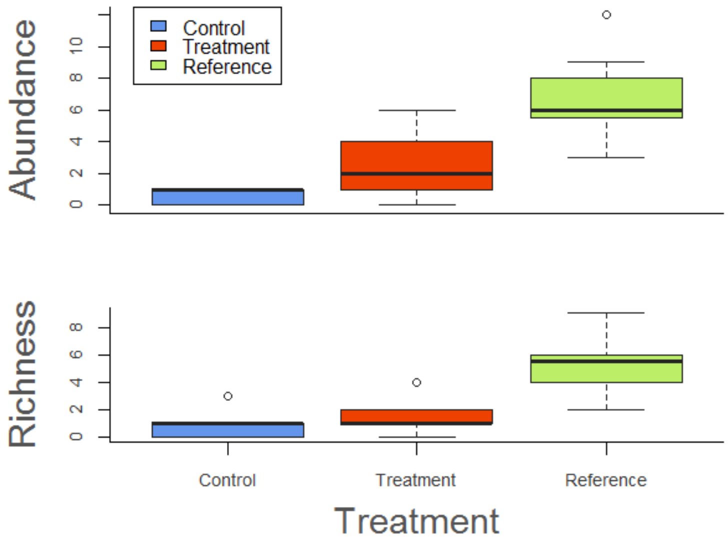

Figure 6-17: **Boxplot showing relative abundance (number of individuals per survey; top panel) and richness (number of species per survey; bottom panel) at each treatment type in Bush Arm in 2015**

Five species were unique to control and treatment transects in Bush Arm: Spotted Sandpiper, Killdeer, Tree Swallow, Barn Swallow, and Savannah Sparrow. These are all open-country species that are expected within the drawdown zone of Kinbasket Reservoir. Three species in treatment transects were not detected in controls, and three species in control transects were not detected in treatments (Figure 6-18). However, these differences likely pertain to stochastic detection rather than micro-site differences. That many of the most frequently detected species in treatments and controls are those that utilize the drawdown zone indicates that, over time, we should be able to detect trends related to bird occupancy and use of treatment and control areas as the detection frequency of these species increases

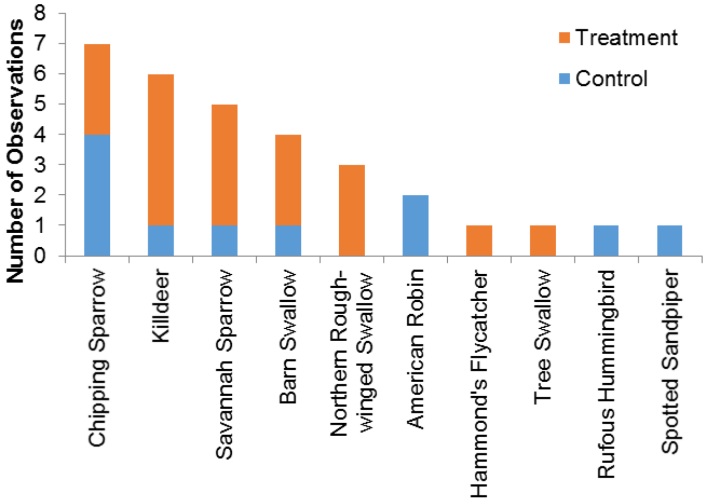

Figure 6-18: **Number of observations per species recorded in pre-treatment (orange) and control (blue) transects in Bush Arm in 2015.**

Reference point count surveys recorded 164 individuals of 24 species (Figure 6-19; constraining the data by distance and species group). Based on these constrained data, reference sites had an average Sørensen Similarity of 58.2 per cent (range: 44.4 – 76.9 per cent), with a mean of 13.5 species per site. Approximately three-quarters of all species detected in the reference sites of Bush Arm were unique to references, including the most frequently detected species (Figure 6-19). As at Canoe Reach, most of the species detected in reference sites in Bush Arm are typical of forested landscapes, and with those shared between reference and treatment/control transects favoring more open or shrubby habitats.

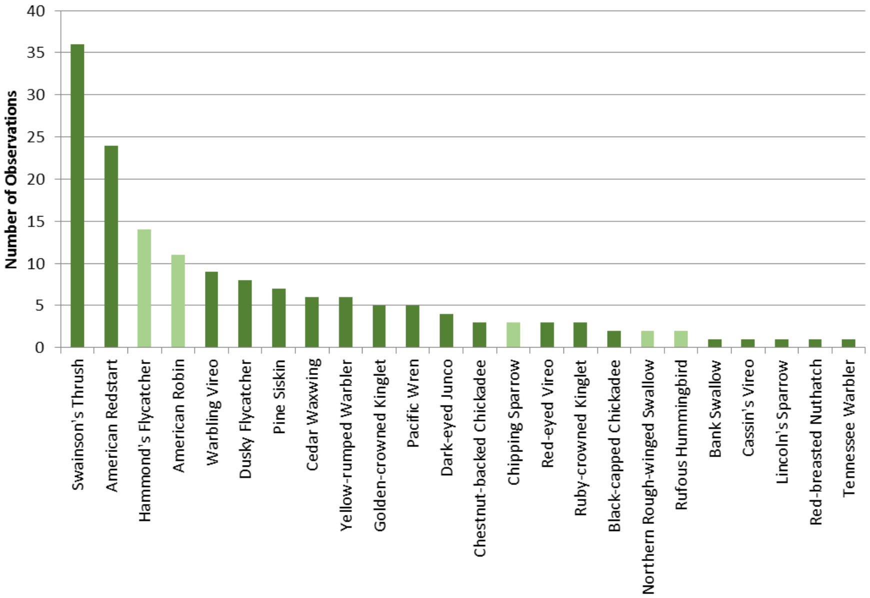

Figure 6-19: Number of observations per species recorded in reference plots in Bush Arm in 2015. Dark green bars indicate species unique to reference plots in Bush Arm in 2015

Nesting Evidence

Nest searches in Bush Arm were conducted over the same period as line transects. Four nests were found between June 22nd and 23rd, and two nests and two recently fledged broods were found between July 9th and 11th (Table 6-13; Figure 6-20).

Table 6-13: Details of bird nests located in Bush Arm in 2015 (site codes provided in Table 3-2)

Site	Species	Date Found	Nest Substrate	Nest Fate
CHT	Spotted Sandpiper	22 June	Ground	Unknown
CHT	Mountain Bluebird	22 June	Tree Cavity	Probable Fail
CHT	Killdeer	10 July	Ground	Success
BAC-N	Killdeer	11 July	Ground	Fail
BAC-N	Spotted Sandpiper	11 July	Ground	Success
BAC-S	Chipping Sparrow	23 June	Ground	Probable Success
BAC-S	Northern Flicker	23 June	Tree Cavity	Probable Success
BAC-S	Spotted Sandpiper	9 July	Ground	Probable Fail

As expected based on the available habitat, most nests were located on the ground. One Mountain Bluebird nests was located 0.2 m up in a hollow stump at the edge of the drawdown zone, and a Northern Flicker nest was approximately 1.5 m high in a stump. Two shorebird broods (one Spotted Sandpiper and one Killdeer) were first found after they had left the nest (which occurs shortly after hatching), and so the exact nest location was undetermined. Several nest failures were documented from Bush Arm. The Mountain Bluebirds were building their nest when discovered on 22 June. By 10 July the nest site was submerged under water, below the level of the reservoir. It is not known if any eggs had been laid. Another nest (Spotted Sandpiper) had four eggs on 24 June; when revisited on 10 July the nesting location was inundated, but the chicks would have likely survived if they hatched between the check dates, and so the nest fate is unknown. Two additional nests failed due to disturbances: one Spotted Sandpiper nest failed as a result of being stepped on (two eggs destroyed completely, with young appearing close to hatching based on their developmental state), and a Killdeer nest was abandoned.

Out of the six physical nests found, three were found while the adults were incubating eggs, one while the young were still in the nest, one during nest-building, and the final after eggs had been laid but the nest abandoned. Successful or probably successful nesting attempts were witnessed for Northern Flicker, Chipping Sparrow, Spotted Sandpiper and Killdeer. As with Canoe Reach, the shorebird species offer the greatest likelihood of short-term response to additional nesting opportunities through woody-debris removal. If revegetation occurs, the number of sparrow nesting attempts is also expected to increase.

Figure 6-20: Nest photos from the 2015 Bush Arm monitoring season. Left: an abandoned Killdeer nest at Bush Arm Causeway North. Right: a stump with an active Northern Flicker nest at Bush Arm Causeway South

6.5 Incidental Observations

Incidental observations are useful for recording species that would otherwise not be detected during targeted surveys at each site. These incidental records of wildlife species contribute to the knowledge of these study sites at Kinbasket Reservoir (Figure 6-21). Mammal presence at upland reference and drawdown zone sites are summarized in Table 6-14 and Table 6-15 respectively. For example, a Canada Lynx (*Lynx canadensis*) was sighted on June 21, 2015 at the south end of the Bush Arm Causeway as it crossed the logging road in pursuit of a weasel (*Martes* sp.). On June 20, 2015, our crews sighted a North American Porcupine (*Erethizon dorsatum*) at Chatter Creek, just upland of the reservoir near the parking area. A dead black bear was also found at Chatter Creek, in the treed area just above the maximum extent of the reservoir (found July 9, 2015).

Of the 22 incidental observations of birds made in 2015, eight species were detected only incidentally (not recorded during bird surveys). These included birds found outside of survey plots. For e.g., at Packsaddle Creek North twelve American White Pelican (*Pelecanus erythrorhynchos*) were observed standing in shallow water at the shoreline of the reservoir, sleeping, on June 16, 2015. At Packsaddle Creek South one adult and two fledgling great-horned owl (*Bubo virginianus*) were detected in the upland reference area (along the access road to the drawdown zone) on July 5, 2015. Additional bird species that were only detected incidentally included: Common Merganser (*Mergus merganser*), Gray Jay (*Perisoreus canadensis*), LeConte's Sparrow (*Ammodramus leconteii*), Mountain Bluebird (*Sialia currucoides*), Osprey (*Pandion haliaetus*), and Townsend's Solitaire (*Myadestes townsendi*).

Figure 6-21: Photographs taken of incidental species observations during the 2015 monitoring year at Kinbasket Reservoir. Mammal sightings (top): Canada Lynx at Bush Arm Causeway, North American Porcupine at Chatter Creek, and White-tailed Deer at Packsaddle Creek. Bird sightings (bottom): fledgling Great-horned Owl and Osprey at Packsaddle Creek, LeConte's Sparrow at Bush Arm Causeway (Photos © Andrew Davis and Charlene Wood)

Seven species of small mammals were identified from pitfall trap collections at Kinbasket Reservoir (2014 and 2015 study years combined), including two vole species and five shrew species (Table 6-16). Notably, the vagrant shrew, *Sorex vagrans*, was found in both years at Canoe Reach, and in Bush Arm in 2015 (20 individuals). This species is infrequently encountered and historically was known from the original Kinbasket Lake location (prior to dam operation). Our records from Canoe Reach represent the northernmost known record for the species in British Columbia. Vertebrate experts at the Royal BC Museum have been contacted and provided specimens to confirm this record and update the known distribution of this species in BC.

Table 6-14: **Incidental sign of mammal presence (P) in the drawdown zone of Kinbasket Reservoir by site and reach in 2015.** Observations included visual sightings, mortalities (*), tracks, and scat of all species, excluding small mammals. Deer species (White-tailed and Mule deer) are pooled due to difficulty in differentiating these species by pellets and tracks. BAC= Bush Arm Causeway, CHT= Chatter Creek, HOPE= Hope Creek, GDF= Goodfellow Creek, PS= Packsaddle Creek, and YJ= Yellowjacket Creek; N= North, S= South; M= Mammal

			Bush Arm					Canoe Reach		
Species Code	**Scientific Name**	**Common Name**	**BAC-N**	**BAC-S**	**CHT**	**HOPE**	**GDF**	**PS-N**	**PS-S**	**YJ**
M-URAM	*Ursus americanus*	Black Bear			P*	P				
M-LYCA	*Lynx canadensis*	Canada Lynx		P						
M-CALU	*Canis lupus*	Grey Wolf		P					P	
M-CALA	*Canis latrans*	Coyote			P				P	P
M-MARTES	*Martes* sp.	Weasel sp.					P			
M-ALAM	*Alces americanus*	Moose					P			
M-CECA	*Cervus canadensis*	Elk	P	P					P	
M-CERVID	Cervidae	Moose/Elk	P							
M-ODSP	*Odocoileus* sp.	Deer sp.		P	P	P*	P		P	
M-LEAM	*Lepus americanus*	Snowshoe hare				P				

Table 6-15: **Incidental sign of mammal presence (P) in the upland reference sites of Kinbasket Reservoir by site and reach in 2015.** Observations included visual sightings, mortalities (*), tracks, and scat of all species, excluding small mammals. Deer species (White-tailed and Mule deer) are pooled due to difficulty in differentiating these species by pellets and tracks (abbreviations as in Table 6-14)

			Bush Arm			Canoe Reach	
Species Code	**Scientific Name**	**Common Name**	**CHT**	**GDF**	**HOPE**	**PS-N**	**PS-S**
M-URAM	*Ursus americanus*	Black Bear		P		P	
M-ODSP	*Odocoileus* sp.	Deer sp.		P	P	P	P
M-ERDO	*Erethizon dorsatum*	North American Porcupine	P				
M-LEAM	*Lepus americanus*	Snowshoe hare		P	P	P	P
M-TAHU	*Tamiasciurus hudsonicus*	Red squirrel				P	

Table 6-16: Incidental records of small mammals from pitfall trap mortalities at Kinbasket Reservoir by site and reach in 2014 and 2015 (site abbreviations as in Table 6-14).

Year	Reach	Site		***Microtus longicaudus***	***Microtus pennsylvanicus***	***Microtus* sp.**	***Sorex cinereus***	***Sorex hoyi***	***Sorex monticolus***	***Sorex palustris***	***Sorex vagrans***	***Sorex* sp.**	**Total**
2014	Canoe	**PS-N**	DDZ		1		9	3			1		**14**
			REF	6	1		6						**13**
		PS-S	DDZ		4		21	4			2		**31**
			REF		2		9	2					**13**
		VP-N	DDZ		5		9				2		**16**
			REF				3	3					**6**
		VP-S	DDZ		3		3				7		**13**
			REF		1		12				1		**14**
		YJ	DDZ		12		3			1	3		**19**
			REF				15						**15**
2015	Canoe	**PS-N**	DDZ					1			1		**2**
			REF									1	**1**
		PS-S	DDZ				1	1					**2**
			REF						1				**1**
		YJ	DDZ			4	1				1		**6**
			REF				3						**3**
2015	Bush	**BAC-N**	DDZ				1						**1**
		BAC-S	DDZ								2		**2**
		CHT	DDZ						1				**1**
		GDF	REF				2						**2**
		HOPE	REF				1						**1**
Total				**6**	**29**	**4**	**99**	**14**	**2**	**1**	**20**	**1**	**176**

Table 6-17: **Incidental visual and auditory detections of bird species presence (P) by site and reservoir context in 2015.** BAC= Bush Arm Causeway, CHT= Chatter Creek, HOPE= Hope Creek, GDF= Goodfellow Creek, PS= Packsaddle Creek; N= North, S= South

		Bush Arm									Canoe Reach		
		BAC-N	**BAC-N**	**BAC-S**	**CHT**	**CHT**	**GDF**	**GDF**	**HOPE**	**HOPE**	**PS-N**	**PS-S**	**PS-S**
Scientific Name	**Common Name**	**DDZ**	**REF**	**DDZ**	**DDZ**	**REF**	**DDZ**	**REF**	**DDZ**	**REF**	**DDZ**	**DDZ**	**REF**
Pelecanus erythrorhynchos	American White Pelican										P		
Mergus merganser	Common Merganser						P						
Gavia immer	Common Loon				P		P					P	
Haliaeetus leucocephalus	Bald Eagle						P						
Pandion haliaetus	Osprey											P	
Bubo virginianus	Great Horned Owl												P
Hylatomus pileatus	Pileated Woodpecker					P		P					
Colaptes auratus	Northern Flicker			P									
Bombycilla cedrorum	Cedar waxwing	P						P					
Turdus migratorius	American Robin	P											
Catharus ustulatus	Swainson's Thrush	P											
Myadestes townsendi	Townsend's Solitaire									P			
Vireo gilvus	Warbling Vireo	P											
Perisoreus canadensis	Gray Jay		P										
Spizella passerina	Chipping Sparrow			P									
Passerculus sandwichensis	Savannah Sparrow			P									
Ammodramus leconteii	LeConte's Sparrow			P									
Junco hyemalis	Dark-eyed Junco									P			
Sialia currucoides	Mountain Bluebird				P								
Stelgidopteryx serripennis	Northern Rough-winged Swallow			P									
Actitis macularius	Spotted Sandpiper	P		P					P				
Charadrius vociferus	Killdeer	P							P				

7.0 DISCUSSION

The 2015 monitoring year focused on first year post-treatment sampling at Canoe Reach and pre-treatment sampling at Bush Arm. The efficacy of physical works trials, such as woody debris removal and creation of mounds/windrows of soil and wood are being assessed under CLBMON-11A for enhancement of drawdown zone habitats. Future years of monitoring data are required to assess the short-term change in taxa abundance, richness, composition, and indicators. However, as species ecologies are relatively well known for the focal taxa, some predictions on how individual taxa will respond to successful revegetation treatments are provided in Table 7-1.

As implied by the variable species responses (negative, neutral, positive) predicted in Table 7-1, indicator analyses and community ordination will be useful in resolving turnover in species and associations between species and treatments and habitat characteristics. Indicator Species Analyses can be used to determine the degree of habitat-association and also to detect changes in the frequency occurrence and abundance of each species within treatments and/or sites. As treatment habitats change and become more/less favorable to a species, the indicator value of that species will increase/decrease (respectively).

For example, the ground beetle *Bembidion planatum* prefers open habitats with bare ground and was a strong indicator of treatments at PS-N and YJ in 2014. As vegetation cover increases, we expect this to decrease in treatment areas and we expect species such as *Amara* spp. to increase. These initial bare soil associated taxa detected in 2014 and 2015 will be replaced successively by species more tolerant of ground cover and vegetation cover.

Table 7-1: Preliminary predictions for taxon responses to future habitat change in treatment areas based on known species ecology. Predictions assume the successful revegetation of treatment plots, which will depend on the site, reach, and treatment applied

		Predicted response to treatment:	
Taxon Group	**Taxon**	**Direction**	**Description**
VEGETATION:			
Herb layer	*Carex* spp., *Equisetum* spp., Grasses, *Polygonum* spp.	Positive	• Colonization and increased percent cover, especially in upper elevation bands and in plots protected from further wood accumulation
Shrub layer	*Salix* spp., *Rosa acicularis, Cornus stolonifera, Populus spp., Betula spp.*	Positive	• Colonization and increased percent cover of these shrubs that are already present in the drawdown zone (expected within the uppermost elevation band)
EPIGAEIC ARTHROPODS:			
Spiders	Ground-running spiders: *Pardosa* spp.	Negative	• Initial colonization of disturbed plots; subsequent decline in abundance and frequency as revegetation progresses
	Drassodes neglectus	Neutral to negative	• An open-habitat species that may remain at similar abundance in treatment plots or decline if vegetation cover increases
	Pirata piraticus	Neutral to positive	• Associated with marshy habitats- abundance may increase in treatment plots if vegetation cover improves site moisture retention
	Ambush hunters (e.g., Xysticus spp.), Sheet-web (e.g., *Agelenopsis* spp., *Agyneta* spp.) and Space-web weavers (e.g., *Euryopis* spp.)	Positive	• Increased density in plots where herb and shrub cover have increased • Funnel-web weavers expected to increase with grass and low-lying vegetation cover over previous bare ground • Space-web and orb-weavers expected increase with increased structural heterogeneity (i.e., herb and shrub layer establishment)
Ground beetles	*Bembidion planatum, Cicindela tranquebarica, Nebria* spp.	Negative	• Decreased abundance in treatment areas with increased vegetation cover as these species prefer open-habitat with bare ground
	Cicindela longilabris, *Cylindera terricola*; *Agonum corvus* and *A. metallescens; Bembidion bimaculatum, B. obscurellum,* and *B. rupicola*	Neutral to negative	• Abundance expected to either remain similar (if vegetation is sparse) or decline (for dense vegetation) for these species that prefer open habitat with only sparse vegetation cover
	Pterostichus adstrictus	Neutral to positive	• This generalist predator is found equally in open and closed habitats- we expect an increase in abundance of this species in treatments overtime due to increases in prey density that are expected as vegetation cover increases (e.g., Lepidoptera eggs and larvae)
	Agonum retractum, Pterostichus herculaneus, P. neobrunneus, P. protractus, Scaphinotus spp., Platynus decentis	Neutral to positive	• These closed-habitat/forest species will potentially increase in the uppermost elevation band of the treatments if vegetation cover provides adequate shade, however they are expected to be more dominant in upland forests

		Predicted response to treatment:	
Taxon Group	**Taxon**	**Direction**	**Description**
	Agonum sordens, *A. gratiosum, Pterostichus riparius*	Positive	• These species are mostly associated with open ground near water with dense vegetation, thus we expect an increase in abundance of these species, especially in the upper elevation band of the treatments where vegetation is more likely to become dense
	Amara spp.	Positive	• Unique among the ground beetles, some *Amara* spp. augment their carnivorous diet with seeds and vegetation. Outbreaks of *Amara* have been reported in agricultural fields in Alberta (Floate and Spence, 2015). Thus we expect an increase in *Amara* abundance as seed-bearing plant cover increases; other Amara spp. feed on grasshopper eggs and caterpillars, which are also expected to increase in density with revegetation of treatments
	Platynus mannerheimi	Positive	• Less associated with forests than *P. decentis*, this species is expected to increase in treatments with peaty soil and cover of *Carex* spp. (potentially VP-N)
Rove beetles	*Dinothenarus pleuralis, Tachinus* spp.	Neutral to positive	• Mostly closed-habitat species found in upland reference plots- may appear in low densities within the uppermost elevation bands of treatment plots with dense vegetation cover
	Tachyporus spp.	Positive	• Increased abundance in treatment plots with dense vegetation and increased prey density; found in open fields, where they are generalist predators of aphids, springtails, nematodes, fly larvae, etc.; when insect prey are not available, *Tachyporus* spp. will feed on pollen or fungi
	Stenus spp.	Positive	• These species are water-striding predators found in moist treatment sites and are expected to increase as prey densities increase with vegetation establishment
	Rove beetles (family as a whole)	Positive	• Currently rove beetle abundance and richness is very low for drawdown zone habitats- a general increase in abundance of this family is expected with increased vegetation cover
BIRDS: Songbirds and other breeding birds	Killdeer, Spotted Sandpiper	Positive to Negative	• Initially will increase in treatment plots where woody debris is cleared (nest on rocky, bare ground) • Will tolerate sparse vegetation but will decline or be excluded if treatments become densely vegetated
	Savannah Sparrow	Positive	• Increased abundance and nesting in treatment plots with increased cover of grasses and other vegetation

Focal taxa selected for monitoring (ground-dwelling arthropods and birds) were selected due to their utility as indicators of habitat change. Our monitoring of these taxa is designed to detect responses to changes in environmental conditions, habitat quality, and/or prey densities in the drawdown zone of Kinbasket Reservoir resulting from treatment applications. So far, results have outlined the species-specific responses to treatments, and for arthropods site-specific differences have also been assessed. Future years will explore the cumulative change in focal taxa in treatments (compared to controls) as well as inter-annual changes. Where possible, site-by-treatment responses will be examined.

Whether post-treatment vegetation establishment is successful is yet to be determined and will likely to depend on site-specific attributes and exposure to wood debris accumulation or erosion from reservoir inundation. The effectiveness of revegetation and physical works trials that have been implemented in Kinbasket Reservoir are being assessed under the CLBMON-9 program. Focal taxa will continue to be monitored in order to determine if taxa are responding to local changes in habitat quality.

It will be important to consider the development of physical works prescriptions for the drawdown zone of Kinbasket Reservoir. Developing prescriptions to protect or enhance high quality habitats that exist in the drawdown zone (e.g., Ptarmigan Creek, Bush Arm Causeway, Ponds in the Valemount Peatland) would contribute to an overall improvement in wildlife habitat suitability (if the physical works are built). For example, log booms should be developed at select sites to exclude additional log accumulation, and woody debris should be removed from those sites in accordance with the study design.

Additional efforts should be directed on limiting any new woody debris accumulation on the 2014 treatment plots. In the absence of protection, our experimental plots could be annually compromised by changes in woody debris distribution. For example, cleared treatment plots may continually receive woody debris inputs, which would compromise their ability to assess the efficacy of woody debris removal for revegetation. Wood that was present on 2014 control plots could also be displaced, reducing the efficacy of these plots to act as experimental controls. Control and Treatment plots should be protected by log booms, where possible, in order to ensure the long-term efficacy of this monitoring program. The ability for the treatment (i.e., the removal areas) to remain devoid of woody material also needs to be assessed as does the integrity of the log boom.

Provided that treatment plots are protected from wood debris accumulation (by installation of log booms and/or the construction of mounds) we expect there to be an increase in the natural cover of vegetation on treatment plots. Within Canoe Reach, revegetation is expected to be most successful at the Valemount Peatland North site, due to the high organic matter content in the soil and installation of log booms around the treated area. In turn, we expect the open-habitat associated fauna that were most indicative of these treatment areas in 2014 to decrease in abundance. Species turnover will progressively result in assemblages that are associated with increased vertical structure and vegetation cover. Where non-native species (plants and beetles) occur, we expect there to be a slow replacement of those species by native species.

Following natural revegetation of the treatment plots, we expect increased richness and abundance of songbirds as a result of greater habitat heterogeneity. Of the songbird species using the drawdown zone, Savannah Sparrow is relatively common and this species is expected to colonize treatment areas following revegetation. Additional sparrow and warbler species would be expected if a shrub layer develops, which is most likely to happen at the upper elevations of the drawdown zone (i.e., >753 mASL). Overtime, this may lead to increases in the richness and abundance of songbirds in the drawdown zone. Increases in insect abundance may also translate to increased densities of breeding birds relative to pre-treatment conditions.

Currently, only one treatment area was protected in Canoe Reach in 2014, thus these predictions may apply only to the Valemount Peatland North site. All other treatment areas will likely accumulate woody debris from adjacent control areas and from other areas of Kinbasket Reservoir, which will make it difficult to detect treatment effects in these areas. One common pattern that emerged from vegetation and arthropod surveys was that treatment plots had a higher abundance and richness of non-native species. This is not surprising, given that invasive species are often quick to colonise recently disturbed sites. As treatment plots recover from the initial disturbance of woody-debris removal, we expect a decrease in these non-native species.

Since 2014, we have focused on species-level classifications of spiders and beetles due to their utility as indicators of disturbance gradients (Niemela et al. 1993, Work et al. 2004, Cobb et al. 2007, Buddle et al. 2006, Larrivée et al. 2007; Pinzon et al 2012, 2013a). These taxa have been successfully used to monitor ecological changes in riparian, forest, and grassland ecosystems. Assemblages of arthropod species were distinct in treatment and control plots, only one year post-treatment. This supports the utility of ground-dwelling arthropods in monitoring habitat change.

The species richness and abundance of songbirds did not differ between control and treatment plots, but species composition did. Evidence of nesting was generally low in all areas, which may reflect the small size of the plots relative to territory requirements of many breeding bird species. If vegetation establishes on treatment plots, the number of territories and nests of bird species might increase, indicating that the quality of the habitat has improved for birds. However, this could take some time as vegetation establishment is generally a slow process. Currently, it appears that treatments may be of equivalent or lower suitability to breeding birds than controls. This is not unexpected given the short time period since woody debris removal, and more years of data will help determine trends related to bird richness, abundance, or nesting suitability.

7.1 Management Questions

The current status of our ability to answer each of the four management questions associated with CLBMON-11A is summarized below.

MQ1: How effective is the revegetation program at enhancing and increasing the utilization of habitat in the drawdown zone by wildlife such as amphibians, birds, small mammals, and ungulates?

Amphibians are currently only being monitored at Valemount Peatland North (under CLBMON-37/58). At that site there has been increased utilisation by

Western Toad and Columbia Spotted Frog. There has been an increase in breeding by these species at the woody debris removal treatment since 2014 that has resulting in the production of a large number of tadpoles. The survival of metamorphs at this site is yet to be determined, but at least initially it appears that the woody debris removal trial was successful in this area. The efficacy of the log boom will need to be determined in future years when the reservoir is predicted to reach full pool. Barring further accumulation of wood over the wet areas of the treatment, revegetation should progress.

Currently bird abundance appears similar (low) in the control and treatment plots. However certain species seem to be increasingly utilising the cleared treatment sites at Canoe Reach. Savannah Sparrow, Spotted Sandpiper, and Killdeer were documented using treatments more than controls. These species are known to be open-habitat associated, in areas with low/sparse vegetation

Small mammals are not currently being monitored under CLBMON-11A, however incidental captures in pitfall traps provide some opportunistic data on density of small mammals in treatment and control plots. In 2014, most drawdown zone plots had a higher density of shrews than upland reference sites. Year-to-year comparisons are not possible, since we changed our pitfall trap fluid to a less toxic alternative in 2015. We do expect shrews and granivorous small mammals to respond to treatment applications long-term if vegetation cover increases (along with arthropod abundance).

Ungulates are not currently being monitored in this study. The treatment areas are not appropriate for targeting these wildlife species. However, our incidental observations support that ungulates are traversing through the drawdown zone at many of the treatment sites and are likely to benefit if plants establish of the appropriate species for forage.

MQ2: To what extent does revegetation increase the availability of invertebrate prey (e.g. arthropods) in the food chain for birds, amphibians and small mammals?

We are currently monitoring the abundance of beetles and spiders at each sites and treatment type. However, we are not monitoring all arthropod taxa that contribute to the diet of wildlife (e.g., aerial insects, caterpillars, grasshoppers) and we are not testing the consumption of arthropods or the diet preferences of birds, amphibians, and small mammals. We will answer this management question based on our data of ground-dwelling arthropods (spiders and beetles). Abundance patterns are so far extremely variable between sites and treatments.

In 2014, insectivorous small mammals (*Sorex* spp.) were collected in roughly equal abundance across treatment, control, and reference plots. Abundance of shrews did not coincide with plots that had high arthropod abundance. However, this study was not meant to survey small mammals and all captures were incidental. Any investigation of the food chain linkages between arthropod taxa and birds, amphibians, or small mammals is beyond the scope of the study.

MQ3: Are revegetation efforts negatively impacting wildlife in the drawdown zone? For example, does revegetation increase the incidence of nest mortality in birds or create sink habitat for amphibians?

This study does not address negative impacts to wildlife in the drawdown zone. The determination of nest mortality or sink habitats requires specific studies, with hypotheses not addressed under this study. Based on other studies of nest mortality (CLBMON-36) and impacts on amphibians and reptiles (CLBMON-37 & 58), it is not known if revegetation or physical works trials have any negative impacts, but none are suspected thus far.

We will continue to document nesting evidence and fate of nest in future years to help answer this management question. A pair of Mountain Bluebirds were building a nest in a cavity of a stump in the drawdown zone of Bush Arm on 22 June, 2015. By 10 July the nest site was submerged under water, below the level of the reservoir. It is not known if any eggs had been laid. Another nest (Spotted Sandpiper) had four eggs on 24 June, 2015; when revisited on 10 July the nesting location was inundated. Chicks would have likely survived if they hatched between the check dates, so the nest fate is unknown.

MQ4: Which methods of revegetation are most effective at enhancing and increasing the utilization of wildlife habitat in the drawdown zone?

Based on the results obtained thus far for CLBMON-11A, it appears that all conventional methods of revegetation were ineffective at enhancing and increasing the utilization of wildlife habitat in the drawdown zone. As found in CLBMON-9 (based on four years of results), only the sedge plug revegetation treatment had any establishment success, but even then only in very limited areas (Hawkes et al. 2013).

Woody debris removal has the potential to enhance and increase the utilization of wildlife habitat in the drawdown zone, but more years are of study are needed to determine the effectiveness of this approach. Initial results from vegetation surveys suggest that treatment sites are rapidly and naturally recolonized by plant species. The longevity of vegetation on these plots is precarious due to the inevitable re-accumulation of wood each year. Thus, any positive effects observed in early years post-treatment may be short-lived.

7.2 Management Questions - Summary

Our ability to address each of the management questions is summarized below (Table 7-2). The methods applied in previous years (e.g., small mammal live-trapping, ungulate surveys) are not well-suited to answering the management questions associated with CLBMON-11A. The program was modified for the 2014 and 2015 sampling yeas to concentrate on the efficacy of woody debris removal as an alternative revegetation technique. The current trends in our data will be monitored overtime for changes in vegetation and focal taxa (e.g., ground-dwelling spiders and beetles and breeding birds). Data collected in future survey years will clarify conclusions for each management question.

Table 7-2: Outline of CLBMON-11A Management Questions (MQs), scope of results, methodological constraints, and sources of uncertainty for the 2015 monitoring year

MQ	Able to Address MQ?	Scope		Sources of Uncertainty
		Current supporting results	Suggested modifications to methods where applicable	
1: How effective is the revegetation program at enhancing and increasing the utilization of habitat in the drawdown zone by wildlife	Partially	Savannah Sparrow, Spotted Sandpiper, and Killdeer using treatments more than controls Spider and beetle species assemblages are distinct between control and treatment plots at Canoe Reach (one year post-treatment), suggesting major differences in habitat qualities resulting from treatments. Some bare-ground associated arthropods have declined in treatment plots since 2014, possibly due to vegetation cover increases	• Sample treated sites and controls annually (reference sites are not variable and can be sampled less frequently) • Treat additional selected sites for physical works and implement pre-treatment sampling • Protect the long-term integrity of study plots in the drawdown zone by installing physical barriers to exclude woody debris from treatment plots and maintain woody debris in control plots (e.g., install log booms) • Consider the development of physical works prescriptions (e.g., analogous to CLBMWORKS-29B for Arrow Lakes Reservoir) • Catalogue potential revegetation areas (e.g., specific attributes or conditions related to success/failure of revegetation prescriptions)	• Lack of sampling prior to the application of the prescriptions at Canoe Reach • Natural annual population variation • Variable reservoir operations • Bi-annual sampling • Relationships between revegetation or woody debris removal success and site-specific characteristics (e.g., substrate type, soil moisture, aspect, landscape position, etc.) • No measures taken to ensure the long-term integrity of some study plots in the drawdown zone (e.g., log booms)
2: To what extent does revegetation increase the availability of invertebrate prey in the food chain	Partially	General arthropod relative abundance and biomass did not differ between treatment and control transects in revegetation areas (studied prior to 2014). Since 2014 wood removal at Canoe Reach, some sites show clear differences in arthropod abundance between treatment and control areas. Arthropod densities are expected to increase in treatment plots (relative to controls) where vegetation establishment is successful. Results of CLBMON-11B1 show support for correlation between insect biomass and songbird presence (e.g., Hawkes et al. 2012).	• Annual sampling at least of drawdown zone treatment and controls • Select additional sites for physical works and implemented pre-treatment sampling (e.g., woody debris removal) • Consider planting areas with high likelihood of success (i.e., Valemount Peatland North, where substrates are organic, vegetation is colonizing, a log-boom is setup to exclude wood debris, and arthropod abundance is high)	• Lack of sampling prior to the application of the revegetation prescriptions and woody debris removal • Annual population variation • Sampling frequency and variable arthropod phenology • Variable reservoir operations
3: Are revegetation efforts negatively impacting wildlife in the drawdown zone?	Partially	While some species are expected to decline overtime in treatment plots (initial bare-ground colonising arthropod species, exotic species), there is no evidence of negative impacts to wildlife caused by treatment prescriptions	• Management question is better-suited to other studies that currently occur in the region	• Lack of sampling prior to the application of the revegetation prescriptions and woody debris removal • Natural annual population variation • Lack of knowledge regarding wildlife use of the drawdown zone in the winter • Variable reservoir operations

MQ	Able to Address MQ?	Scope		Sources of Uncertainty
		Current supporting results	Suggested modifications to methods where applicable	
4: Which methods of revegetation are most effective at enhancing and increasing the utilization of wildlife habitat in the drawdown zone	Partially	The effectiveness of woody debris removal is likely dependent on site-specific attributes and whether measures are put in place to exclude wood accumulation during subsequent reservoir cycles. Woody debris removal appears to be initially effective at Valemount Peatland North, based on observation of high arthropod and amphibian abundance in the wood removal area since 2014. The effectiveness of physical works trials implemented at Bush Arm will be assessed in future years	• Protect the long-term integrity of study plots in the drawdown zone: install physical barriers to exclude woody debris from treatment plots and maintain woody debris on control plots (e.g., install log booms, where possible) • Select additional sites for physical works and implement pre-treatment sampling (e.g., woody debris removal) • Characterize and catalogue site-specific attributes for all study areas in Kinbasket Reservoir, in order to understand differential responses to treatments	• Lack of sampling prior to the application of the revegetation prescriptions and woody debris removal • No measures taken to ensure the long-term integrity of treatment areas at all study sites • Relationship between revegetation or woody debris removal success and site-specific characteristics (e.g., substrate type, soil moisture, aspect, landscape position, etc.)

Monitoring under CLBMON-11A is currently scheduled to continue in 2016. The following is a summary of the recommendations made for the implementation of CLBMON-11A in future years:

8.0 RECOMMENDATIONS

1. **Increase number of treatment site applications** (woody debris removal and/or mound and windrow sites) for replication and to include sites with other soil seed bank profiles, soil fertility assays, evidence of nascent vegetation establishment, and recent land use history. For example, Pond 12 in Valemount Peatland and the west bank of the Bush Arm Causeway are prime sites for expanding the woody debris removal program for enhancement of wildlife habitats in the drawdown zone. In particular, the enhancement of these areas will benefit breeding amphibian and reptile populations.
2. **Implement pre-treatment sampling** for any new sites selected for treatment application. One of the prior limitations of this program was the lack of pre-treatment data, which makes it difficult to determine if any observed changes are treatment effects or related to pre-existing phenomena. Canoe Reach control and treatment plots are paired, but there are statistical and interpretation benefits in sampling the exact same plot both prior to and after woody debris removal. At Bush Arm we implemented pre-treatment sampling which will greatly improve our ability to decipher post-treatment responses.
3. **Monitor KM 88 in Bush Arm** to assess wildlife use of the areas treated in 2013, which represent a different prescription (larger sedge plugs, larger area, and higher density of planting).
4. **Consider additional physical works prescriptions** for the drawdown zone of Kinbasket Reservoir. Developing prescriptions to protect or enhance high quality habitats that exist in the drawdown zone (e.g., Ptarmigan Creek, Bush Arm Causeway, Ponds in the Valemount Peatland) would contribute to an overall improvement in wildlife habitat suitability (if the physical works are built). For example, log booms should be installed at select sites to exclude additional log accumulation and woody debris should be removed from ponds at the Bush Arm

Causeway. Current assessments will guide whether prescriptions will be replicated in additional sites.

5. **Catalogue the current state of knowledge of revegetation areas.** The revegetation program would benefit from a review of current knowledge of revegetation prescriptions at all study sites in the drawdown zone of Kinbasket Reservoir. This would provide guidance in areas to target for enhancing success of revegetation.
6. **Increase the total revegetated area in select areas of the drawdown zone.** Following the cataloguing of revegetation areas, we recommend 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 number of replicates. Increasing the extent of revegetation areas will increase the likelihood of detecting any changes in wildlife utilization.
7. **Future revegetation.** Some areas might benefit from revegetation post-treatment (physical works trials). The current treatment plots could be split into planted (enhanced revegetation) and un-planted (natural revegetation) treatment areas. Revegetation efforts should be site-specific based on a prescription for that area. If future revegetation is to occur, consider the species of wildlife that are likely to benefit from the revegetation to ensure the appropriate mix of plants is used, that the total area planted is likely to influence wildlife use of the drawdown zone, and that the revegetation prescriptions be applied in a replicated manner with sufficient stratification. Assessing the efficacy of this future revegetation would require long-term monitoring beyond the current scope of this project.

9.0 LITERATURE CITED

Arnett, R.H. and M.C. Thomas. 2001. American Beetles, Volume 1. CRC Press. 464pp.

BC Hydro. 2005. Consultative Committee report: Columbia River water use plan. Volumes 1 and 2. BC Hydro Power Corporation, Burnaby, B.C.

BC Hydro. 2007. Columbia River project water use plan. BC Hydro Generation, Burnaby B.C.

BC Hydro. 2008. Columbia River Project Water Use Plan, Monitoring Program Terms of Reference: CLBMON-11A Wildlife Effectiveness Monitoring of Revegetation in Kinbasket Reservoir. BC Hydro Water License Requirements, Burnaby, B.C.

Bibby C.J., N.D. Burgess, D.A. Hill and S.H. Mustoe. 2000. Bird census techniques. 2nd ed. New York, NY. Academic Press.

Bousquet, Y., P. Bouchard, A.E. Davies and D.S. Sikes. 2013. Checklist of beetles (Coleoptera) of Canada and Alaska. 2nd ed. Pensoft Publishers, Sofia, Bulgaria.

Buddle, C.M., D.W. Langor, G.R. Pohl, and J.R. Spence. 2006. Arthropod response to harvesting and wildlife: implications for emulation of natural disturbance in forest management. Biological Conservation 128: 346–357.

Campbell J.M. 1973. A revision of the genus *Tachinus* (Coleoptera: Staphylinidae) of North and Central America. Memoirs of the Entomological Society of Canada 90: 1–137.

Campbell, J.M. 1979. A revision of the genus *Tachyporus* Gravenhorst (Coleoptera, Staphylinidae) of North and Central America. Ottawa: Entomological Society of Canada.

Cárcamo H., J. Pinzón, R. Leech, and J. Spence. 2014. Spiders (Arachnida: Araneae) of the Canadian Prairies. In Arthropods of Canadian Grasslands (Volume 3): Biodiversity and Systematics Part 1. Edited by H. A. Cárcamo and D. J. Giberson. Biological Survey of Canada. pp. 75-137.

Cardoso, P. S. Pekár, R. Jocqué, and J.A. Coddington. 2011. Global Patterns of Guild Composition and Functional Diversity of Spiders. PLoS ONE 6(6): e21710.

Chen, H. 2015. VennDiagram: Generate High-Resolution Venn and Euler Plots. R package version 1.6.16. https://CRAN.R-project.org/package=VennDiagram

Cobb, T.P., D.W. Langor, and J.R. Spence. 2007. Biodiversity and multiple disturbances: boreal forest ground beetle (Coleoptera: Carabidae) responses to wildfire, harvesting, and herbicide. Canadian Journal of Forest Research 37:1310–1323.

Cooper Beauchesne and Associates Ltd (CBA). 2009a. Monitoring Program No. CLBMON-11A Wildlife Effectiveness Monitoring of Revegetation in Kinbasket Reservoir, Draft Technical Report (Vers 2) – 2008. Unpublished report by Cooper Beauchesne and Associates Ltd., Prince George, BC, for BC Hydro, Water License Requirements, Golden, BC. 67 pp. + Appendices

Cooper Beauchesne and Associates Ltd (CBA). 2009b. Monitoring Protocols for CLBMON-11A: Wildlife Effectiveness Monitoring of Revegetation in Kinbasket Reservoir. Cooper Beauchesne and Associates Ltd. for BC Hydro Water License Requirements.

Cooper Beauchesne and Associates Ltd (CBA). 2010a. Revised Monitoring Protocols for CLBMON-11A: Wildlife Effectiveness Monitoring of Revegetation in Kinbasket Reservoir. Cooper Beauchesne and Associates Ltd. for BC Hydro Water License Requirements.

Cooper Beauchesne and Associates Ltd (CBA). 2010b. Monitoring Program CLBMON-11A: Wildlife Effectiveness Monitoring of Revegetation in Kinbasket Reservoir Final Technical Report – Year 2 (2009). Unpublished report by Cooper Beauchesne and Associates Ltd., Errington, BC, for BC Hydro, Water License Requirements, Golden, BC. 90 pp. + Appendices.

Cooper Beauchesne and Associates Ltd (CBA). 2011a. CLBMON- 11A: Wildlife Effectiveness Monitoring of Revegetation in Kinbasket Reservoir Final Technical Report – Year 3 (2010). Unpublished report by Cooper Beauchesne and Associates Ltd., Errington, BC, for BC Hydro, Water License Requirements, Castlegar, BC. 101 pp. + Appendices.

Cooper Beauchesne and Associates Ltd (CBA). 2011b. Monitoring Program CLBMON-11A: Wildlife Effectiveness Monitoring of Revegetation in Kinbasket Reservoir, Data Summary Report – Year 4 (2011). Unpublished report by Cooper Beauchesne and Associates Ltd., Errington, BC, for BC Hydro Generation, Water License Requirements, Castlegar, BC. 15 pp. + Appendices.

De Caceres, M., and P. Legendre. 2009. Associations between species and groups of sites: indices and statistical inference. Ecology <http://sites.google.com/site/miqueldecaceres/>

de Mendiburu, F. 2014. agricolae: Statistical Procedures for Agricultural Research. R package version 1.2-1. <http://CRAN.R-project.org/package=agricolae>

Dufrêne, M., and P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs 67(3): 345-366.

Ehrlich, P., D.S. Dobkin, and D. Wheye. 1988. The birder's handbook: A field guide to the natural history of North American birds: including all species that regularly breed north of Mexico. New York: Simon & Schuster

Floate, K.D. and J.R. Spence. 2015. ‘Outbreaks’ of *Amara* Stephens (Coleoptera: Carabidae) in Alberta, Canada. The Coleopterists Bulletin 69(1): 114-115.

Foote, J. R., D. J. Mennill, L. M. Ratcliffe and S. M. Smith. 2010. Black-capped Chickadee (Poecile atricapillus), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/039

Goulet, H. 1983. The genera of Holarctic Elaphrini and species of *Elaphrus* Fabricius (Coleoptera: Carabidae): Classification, phylogeny and zoogeography. Quaestiones Entomologicae, 19:219-482.

Ham, D.G. and C. Menezes. 2008. Kinbasket Reservoir Monitoring of the Valemount Peatland. Report prepared by Northwest Hydraulic Consultants for BC Hydro. 23 pp.

Hawkes, V.C. and C. Wood. 2013. CLBMON-58. Kinbasket Reservoir: Monitoring of Impacts on Amphibians and Reptiles from Mica Units 5 and 6 in Kinbasket Reservoir. Year 2 Annual Report – 2013. LGL Report EA3452. Unpublished report by Okanagan Nation Alliance and LGL Limited environmental research associates, Sidney, B.C., for BC Hydro Generations, Water License Requirements, Burnaby, B.C. 69 pp + Appendices.

Hawkes, V.C. and J. Howard. 2012. CLBMON-11B1 Wildlife effectiveness monitoring and enhancement area identification for lower and mid-Arrow Lakes Reservoir: mid- and lower Arrow Lakes Reservoir wildlife enhancement prescriptions. LGL Report EA3274. Unpublished report by LGL Limited environmental research associates, Sidney, B.C., for B.C. Hydro Generation, Water License Requirements, Burnaby, BC. 64 pp. + Appendices.

Hawkes, V.C. N. Hentze, J. Muir, J. Sharkey, J. Gatten, B. McKinnon and P. Gibeau. 2014. CLBMON-11A. Kinbasket and Arrow Lakes Reservoirs: Wildlife Effectiveness Monitoring and Enhancement Area Identification for Lower and Mid-Arrow Lakes Reservoir. Annual Report – 2013. LGL Report EA3450. Unpublished report by Okanagan Nation Alliance, Westbank, B.C. and LGL Limited environmental research associates, Sidney, B.C., for BC Hydro Generation, Water Licence Requirements, Burnaby, BC. 62 pp. + Appendices.

Hawkes, V.C., C. Houwers, J.D. Fenneman and J.E. Muir. 2007. CLBMON-10 Kinbasket Reservoir Inventory of Vegetation Resources. Annual Report – 2007. LGL Report EA1986. Unpublished report by LGL Limited environmental research associates, Sidney, BC, for BC Hydro Generation by LGL Consultants Limited, Sidney. 82 pp.

Hawkes, V.C., J. Sharkey and J. Gatten. 2012. CLBMON-11B1. Kinbasket and Arrow Lakes Reservoirs: Wildlife Effectiveness Monitoring and Enhancement Area Identification for Lower and Mid-Arrow Lakes Reservoir. Annual Report – 2011. LGL Report EA3274. Unpublished report by LGL Limited environmental research associates, Sidney, BC, for BC Hydro Generation, Water Licence Requirements, Burnaby, BC. 77 pp. + Appendices.

Hawkes, V.C., J. Sharkey and P. Gibeau. 2010. Kinbasket and Arrow Lakes Reservoir Monitoring Program No. CBLMON-11 Wildlife Effectiveness Monitoring and Enhancement Area Identification for Lower and Mid-Arrow Lakes Reservoir. LGL Report EA3164. Unpublished report by LGL Limited environmental research associates, Sidney, BC, for BC Hydro Generations, Water License Requirements Burnaby, B.C. 97 pp + Appendices.

Hawkes, V.C., M.T. Miller, and P. Gibeau. 2013a. CLBMON-10 Kinbasket Reservoir Inventory of Vegetation Resources. Annual Report – 2012. LGL Report EA3194A. Unpublished report by LGL Limited environmental research associates, Sidney, B.C., for BC Hydro Generations, Water License Requirements, Castlegar, BC. 88 pp. + Appendices.

Hawkes, V.C., M.T. Miller, J.E. Muir, and P. Gibeau. 2013b. CLBMON-9 Kinbasket Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis. Annual Report – 2013. LGL Report EA3453. Unpublished report by LGL Limited, Sidney, BC, for BC Hydro Generation, Water Licence Requirements, Castlegar, BC. 70 pp. + Appendices.

Hawkes, V.C., P. Gibeau, K.A. Enns, J. Sharkey, J. Gatten, and J. Fenneman. 2011. CLBMON-11B1. Kinbasket and Arrow Lakes Reservoirs: Wildlife Effectiveness Monitoring and Enhancement Area Identification for Lower and Mid-Arrow Lakes Reservoir. Annual Report – 2010. LGL Report EA3164A. Unpublished report by LGL Limited environmental research associates, Sidney, BC, for BC Hydro Generations, Water Licence Requirements, Burnaby, BC. 98 pp. + Appendices.

Larrivée, M., P. Drapeau, and L. Fahrig. 2008. Edge effects created by wildfire and clear-cutting on boreal forest ground-dwelling spiders. Forest Ecology and Management 255:1434–1445.

Larochelle, A. and M.-C. Larivière. 2001. Natural History of the tiger beetles of North America north of Mexico. Cicindela 33(3-4): 41-162.

Larochelle, A. and M.-C. Larivière. 2003. A Natural History of the Ground-Beetles (Coleoptera: Carabidae) of America north of Mexico. Faunistica No 27. Pensoft Publishers, Sofia, Moscow. 583 pp.

Legendre P. and L. Legendre. 2012. Numerical ecology, 3rd edition. Elsevier, Amsterdam.

Legendre, P. and E.G. Gallagher 2001 Ecologically meaningful transformations for ordination of species data. Oecologia 129(2): 271-280.

Lindroth, C.H. 1961-1969. The ground-beetles (Carabidae, excl. Cicindelinae) of Canada and Alaska, parts 1-6. Opuscula Entomologica Supplementa XX, XXIV, XXIX, XXXIII, XXXIV, XXXV.

Marshall, S.A., R.S. Anderson, R.E. Roughley, V. Behan-Pelletier and H.V. Danks. 1994. Terrestrial arthropod biodiversity: planning a study and recommended sampling techniques. A brief. Bulletin of the Entomological Society of Canada 26(1), Supplement, 33 pp.

McCune, B. and J. B. Grace. 2002. Analysis of Ecological Communities. MjM Software, Gleneden Beach, Oregon, USA (www.pcord.com) 304 pages. With a contribution by Dean L. Urban.

McCune, B. and M.J. Mefford. 2011. PC-ORD. Multivariate Analysis of Ecological Data, v. 6.08. MjM Software, Gleneden Beach, Oregon, U.S.A.

McGeoch, M.A. and S.L. Chown. 1998. Scaling up the value of bioindicators. Trends in Ecology and Evolution 13(2): 46-47.

McGeoch, M.A., B.J. Van Rensburg and A. Botes. 2002. The verification and application of bioindicators: a case study of dung beetles in a savanna ecosystem. Journal of Applied Ecology 39: 661-672.

Mielke, P.W. and K.J. Berry. 2001. Permutation methods: A distance function approach. New York: Springer-Verlag.

Niemela, J., D.W. Langor., and J.R. Spence. 1993. Effects of clear-cut harvesting on boreal ground-beetle assemblages (Coleoptera: Carabidae) in western Canada. Conservation Biology 7:551–561.

Oksanen, J., F.G. Blanchet, K. Roeland, P. Legendre, P.R. Minchin, R.B. O'Hara, G.L. Simpson, P. Solymos, M.H.H. Stevens, and H. Wagner. 2014. vegan: Community Ecology Package. R package version 2.2-0.

Pearson, D.L., C.B. Knisley, and C.J. Kazilek. 2006. A field guide to the tiger beetles of the United States and Canada: identification, natural history, and distribution of the Cicindelidae. Oxford University Press, New York. 227 pp. + plates.

Pinzon, J. J.R. Spence, and D.W. Langor. 2012. Responses of ground-dwelling spiders (Araneae) to variable retention harvesting practices in the boreal forest. Forest Ecology and Management, 266: 42–53.

Pinzon, J., J.R. Spence, and D.W. Langor. 2013. Effects of prescribed burning and harvesting on ground-dwelling spiders in the Canadian boreal mixedwood forest. Biodiversity Conservation 22: 1513-1536.

R Core Team. 2016. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org/>

Ralph, C. J., J. R. Sauer, and S. Droege. 1995. Monitoring bird populations by point counts. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA.

Resources Inventory Committee. 1998a. Ground-based inventory methods for selected ungulates: Moose, Elk, and Deer. Page 59. Standards for Components of British Columbia's Biodiversity No. 33. Version 2. Ministry of Environment, Lands, and Parks, Victoria, B.C.

Resources Inventory Committee. 1998b. Inventory methods for terrestrial arthropods. Version 2. Page 42. Standards for Components of British Columbia's Biodiversity, No. 40. Ministry of Environment, Lands, and Parks, Victoria, B.C.

Resources Inventory Committee. 1999. Inventory Methods for Forest and Grassland Songbirds. Standards for Components of British Columbia’s Biodiversity No. 15. Ministry of Environment, Lands and Parks, Victoria, BC. 37 pp.

Smetana, A. 1971. Revision of the tribe Quediini of America north of Mexico (Coleoptera: Staphylinidae). Memoirs of the Entomological Society of Canada 79: 1–303.

Smetana, A. 1995. Rove beetles of the subtribe Philonthina of America north of Mexico (Coleoptera: Staphylinidae) classification, phylogeny and taxonomic revision. Memoirs on Entomology International 3: i–x, 1–946.

Sokal, R.R., and F.J. Rohlf. 1995. Biometry. Third edition. W.H. Freeman and Company, New York.

Sørensen, T. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species and its application to analyses of the vegetation on Danish commons. Biologiske Skrifter 5: 1-34.

Wheelwright, N. T. and J. D. Rising. 2008. Savannah Sparrow (*Passerculus sandwichensis*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/045

Work, T.T., D.P. Shorthouse, J.R. Spence, W.J.A. Volney, and D. Langor. 2004. Stand composition and structure of the boreal mixedwood and epigaeic arthropods of the Ecosystem Management Emulating Natural Disturbance (EMEDN) landbase in northwestern Alberta. Canadian Journal of Forest Research 34:417–430.

10.0 APPENDICES

Appendix A: Tables of supporting results for arthropod monitoring

Table 10-1: Relative abundance (CPUE) of adult arthropods collected in pitfall traps from 2014 and 2015 surveys (spiders and beetles). CPUE = adult catch per trap per day; T= treatment (DDZ), C= Control (DDZ), R= reference (Upland forest). Note: sites surveyed at Canoe Reach differed between 2014 and 2015. *undefined C/T area in the Drawdown zone at Chatter Creek

Year	Reach	Treatment Type	Adult arthropod catch	Cumulative trap-days	Arthropod CPUE
2014	Canoe Reach	T	1169	638.26	1.83
		C	2162	689.71	3.13
		R	2286	664.73	3.44
2015	Canoe Reach	T	2033	1218.03	1.67
		C	1838	1205.22	1.53
		R	6056	1234.63	4.91
2015	Bush Arm	T	802	578.93	1.39
		C	602	588.16	1.02
		DDZ*	289	287.72	1.00
		R	684	291.99	2.34

Table 10-2: Summary of Indicator Species Analysis (ISA1) for 2015 Canoe Reach sampling. Species with significant (p<0.1) "strong" associations with treatment types (IV≥0.5) are given (999 permutations). Control = CON, Treatment = TRT, Reference = REF; taxon groups are indicated with the prefix: A- = Araneae, C- = Carabidae, IV = Indicator Value

Treatment	Indicator Species	Specificity (A-value)	Fidelity (B-value)	IV	p-value
TRT	*A-Drassodes neglectus*	1	1	1	0.049
	C-Amara littoralis	0.8908	1	0.8908	0.083
CON+TRT	*C-Agonum placidum*	1	1	1	0.039
	C-Bembidion obscurellum	1	1	1	0.039
	C-Bembidion planatum	1	1	1	0.039
	C-Syntomus americanus	1	1	1	0.039
	A-Pardosa xerampelina	0.9974	1	0.9974	0.039
CON+REF	*C-Pterostichus pensylvanicus*	1	1	1	0.049
	C-Synuchus impunctatus	1	1	1	0.049
	C-Agonum retractum	0.9934	1	0.9934	0.066
	A-Trochosa terricola	0.9657	1	0.9657	0.049
REF	*A-Ceraticelus fissiceps*	1	1	1	0.039
	A-Tapinocyba minuta	1	1	1	0.039
	A-Walckenaeria exigua	1	1	1	0.039
	C-Pterostichus herculaneus	1	1	1	0.039
	A-Lepthyphantes alpinus	0.9851	1	0.9851	0.039
	A-Walckenaeria directa	0.9773	1	0.9773	0.039
	A-Agelenopsis utahana	0.9765	1	0.9765	0.039
	C-Scaphinotus marginatus	0.9678	1	0.9678	0.039
	A-Agroeca ornata	0.9609	1	0.9609	0.039
	A-Bathyphantes pallidus	0.9529	1	0.9529	0.074
	A-Micaria pulicaria	0.9517	1	0.9517	0.081
	C-Pterostichus protractus	0.9506	1	0.9506	0.074
	A-Clubiona canadensis	0.9288	1	0.9288	0.039
	C-Pterostichus neobrunneus	0.9269	1	0.9269	0.07
	C-Scaphinotus angusticollis	0.9253	1	0.9253	0.062
	C-Platynus decentis	0.9218	1	0.9218	0.083

Appendix B: Figures of supporting results for arthropod monitoring

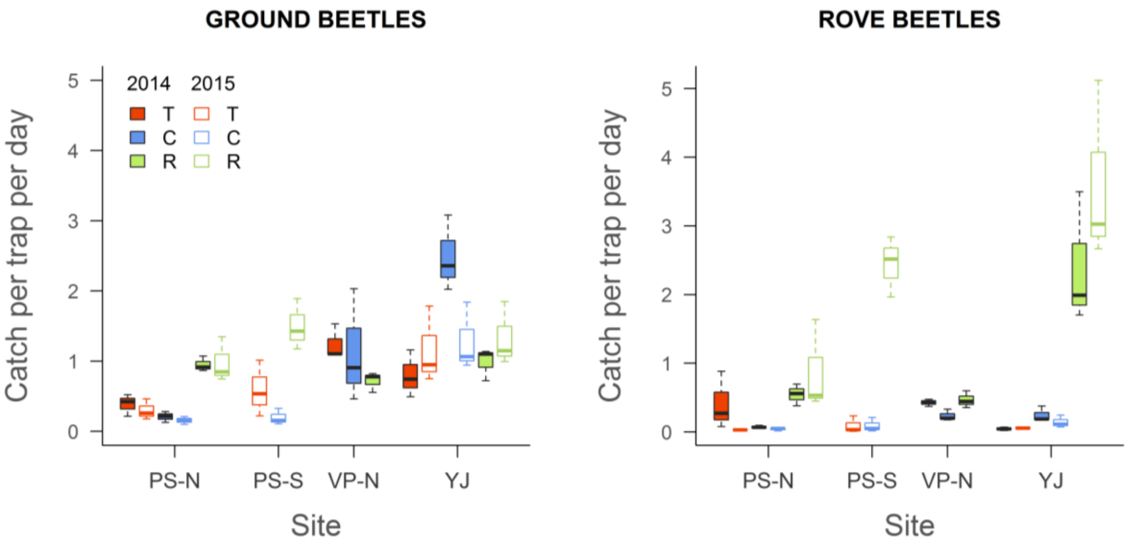

Figure 10-1: Relative abundance (Adult catch per trap-day) of Carabidae (left) and Staphylinidae (right) across treatment types and sites at Canoe Reach. Both 2014 (filled boxes) and 2015 (white boxes) monitoring years are shown, with data pooled at the transect level (n=3 transects per treatment, per site). PS-N = Packsaddle North, PS-S = Packsaddle South, VP-N = Valemount Peatland North, YJ = Yellowjacket Creek

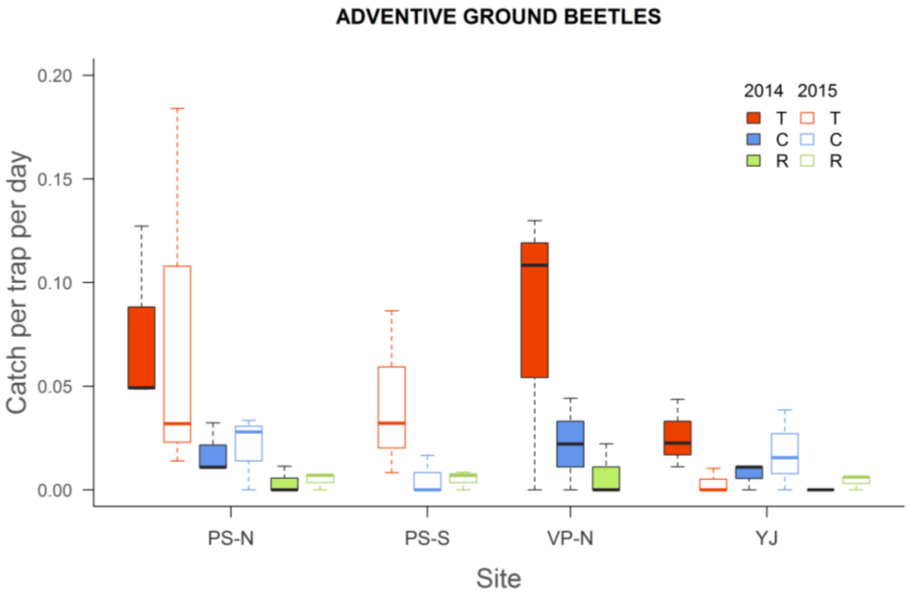

Figure 10-2: Relative abundance (Adult catch per trap-day) of adventive ground beetles across treatment types and sites at Canoe Reach. Both 2014 (filled boxes) and 2015 (white boxes) monitoring years are shown, with data pooled at the transect level (n=3 transects per treatment, per site). PS-N = Packsaddle North, PS-S = Packsaddle South, VP-N = Valemount Peatland North, YJ = Yellowjacket Creek

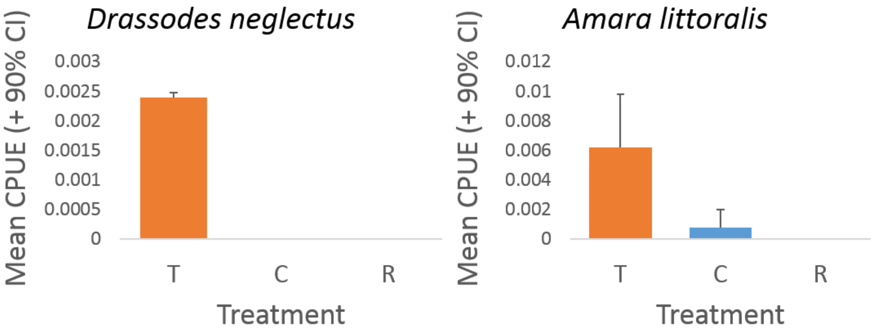

Figure 10-3: Mean relative abundance (individuals per trap per day) of two indicator species for treatment plots at Canoe Reach in 2015. Data pooled at each treatment in each site (n=3)

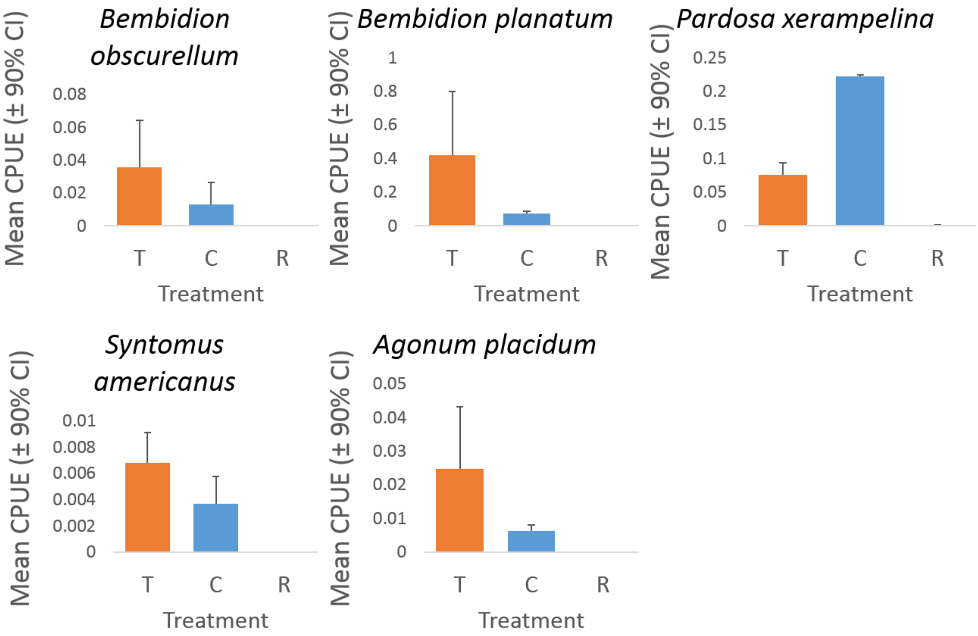

Figure 10-4: Mean relative abundance (individuals per trap per day) of indicator species for drawdown zone plots (control and treatment) at Canoe Reach in 2015. Data pooled at each treatment in each site (n=3)

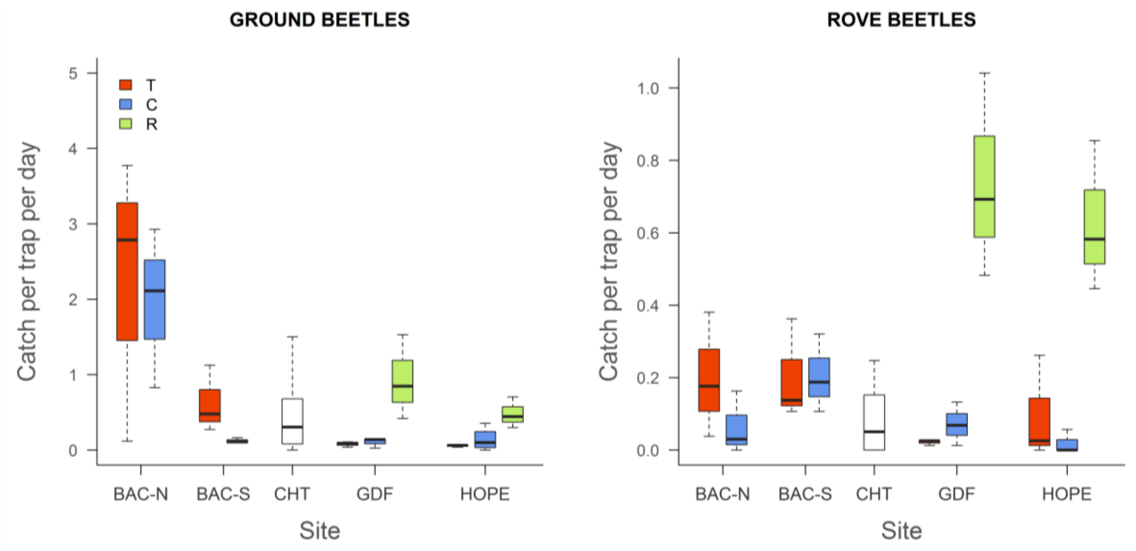

Figure 10-5: Relative abundance (Adult catch per trap-day) of Carabidae (left) and Staphylinidae (right) across treatment types and sites at Canoe Reach. Data pooled at the trap level (2 collections of 3 traps in each treatment in each site). Abundance includes all specimens collected. Chatter Creek (CHT, white) was not sampled in defined pre-treatment/control areas. BAC-N = Causeway North, BAC-S = Causeway South, GDF = Goodfellow Creek, HOPE = Hope Creek (note: unequal scaling of y-axes)

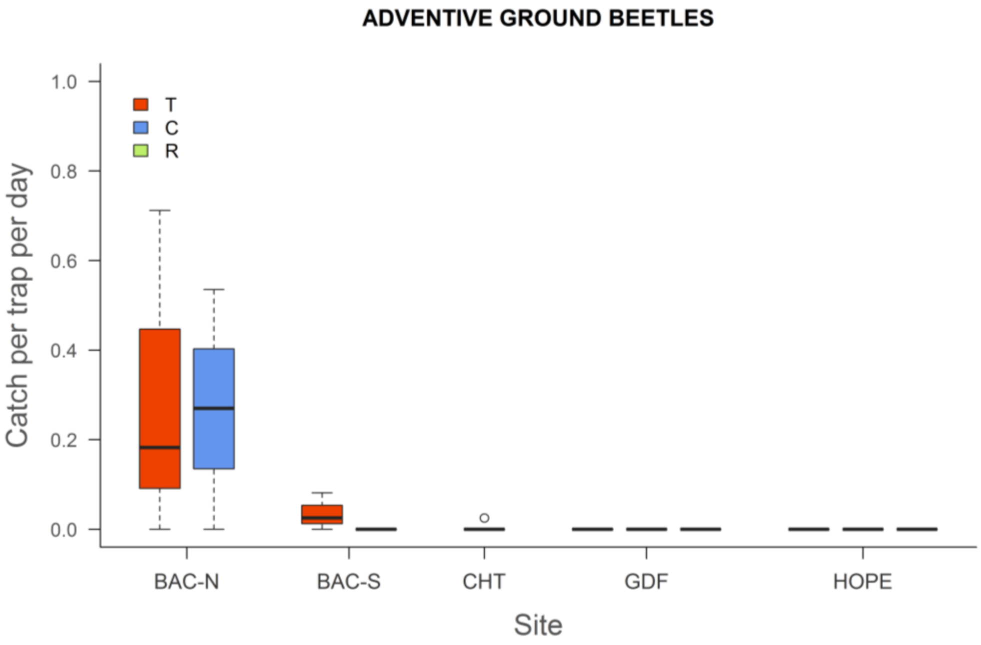

Figure 10-6: Relative abundance (Adult catch per trap-day) of exotic ground beetles across pre-treatment areas and sites at Bush Arm. Data pooled at the trap level (2 collections of 3 traps in each treatment in each site). Abundance includes all specimens collected. Chatter Creek (CHT, white) was not sampled in defined pre-treatment/control areas. BAC-N = Causeway North, BAC-S = Causeway South, GDF = Goodfellow Creek, HOPE = Hope Creek

Appendix C: Bird group, species name, code, and number of observations of all birds detected at all distances during 2015 songbird point count surveys in each treatment. Both reaches are combined (treatment= pre-treatment at Bush Arm); birds listed by taxonomic order. R= reference, C= control, T= treatment

Bird Group: Common Name	Code	Number Observed (all distances)		
		R	C	T
Waterfowl:				
Canada Goose	CAGO	3		1
Mallard	MALL	1		
Upland Game Birds:				
Ruffed Grouse	RUGR	1		
Loons:				
Common Loon	COLO	2		1
Hawks, Eagles, Falcons and Allies:				
Bald Eagle	BAEA		1	1
Shorebirds, Gulls, Auks and Allies:				
Killdeer	KILL	3	2	5
Spotted Sandpiper	SPSA	4	6	5
Wilson's Snipe	WISN	2		
Ring-billed Gull	RBGU		2	
Swifts and Hummingbirds:				
Rufous Hummingbird	RUHU	2	1	1
Kingfishers and Allies:				
Belted Kingfisher	BEKI	1		
Woodpeckers and Allies:				
Red-naped Sapsucker	RNSA	2		
Northern Flicker	NOFL	9		
Pileated Woodpecker	PIWO	3		
Songbirds:				
Alder Flycatcher	ALFL	1		
Willow Flycatcher	WIFL	1		1
Least Flycatcher	LEFL	3	1	1
Hammond's Flycatcher	HAFL	30		1
Dusky Flycatcher	DUFL	17		
Cassin's Vireo	CAVI	1		
Warbling Vireo	WAVI	45	2	3
Red-eyed Vireo	REVI	8	1	
American Crow	AMCR	4		
Common Raven	CORA	4		
Tree Swallow	TRSW	2	1	2
Northern Rough-winged Swallow	NRWS	2		3
Bank Swallow	BKSW	1		
Barn Swallow	BASW		1	4
Black-capped Chickadee	BCCH	11	1	
Mountain Chickadee	MOCH	2		

Bird Group: Common Name	**Code**	**Number Observed (all distances)**		
		R	**C**	**T**
Chestnut-backed Chickadee	CBCH	4		
Red-breasted Nuthatch	RBNU	7	1	
Pacific Wren	PAWR	10		
Golden-crowned Kinglet	GCKI	19		
Ruby-crowned Kinglet	RCKI	7		
Swainson's Thrush	SWTH	85		2
Hermit Thrush	HETH	15		
American Robin	AMRO	19	2	3
Varied Thrush	VATH	5		
Cedar Waxwing	CEWA	17	2	3
Tennessee Warbler	TEWA	1		
Orange-crowned Warbler	OCWA	16	2	1
MacGillivray's Warbler	MACW	5	1	2
Common Yellowthroat	COYE	2		
American Redstart	AMRE	49	2	1
Magnolia Warbler	MGNW	7		1
Yellow-rumped Warbler	YRWA	28	2	
Wilson's Warbler	WIWA	4	1	2
Chipping Sparrow	CHSP	16	5	7
Clay-colored Sparrow	CCSP	3	1	
Savannah Sparrow	SAVS	22	8	4
Lincoln's Sparrow	LISP	9	4	1
White-throated Sparrow	WTSP	8	1	1
Dark-eyed Junco	DEJU	18	2	1
Western Tanager	WETA	6	1	
Red Crossbill	RECR	4		1
White-winged Crossbill	WWCR	2		
Pine Siskin	PISI	41	3	4
Evening Grosbeak	EVGR	1		

Appendix D: Taxon List for spiders (Araneae) adults that were identified to species-level.

Total abundance is not standardized by sampling effort

FAMILY	SPECIES CODE	SCIENTIFIC NAME	GUILD	Canoe Reach		Bush Arm
				2014	2015	2015
Agelenidae	Agel.utah	*Agelenopsis utahana*	Sheet web weavers		48	18
Amaurobiidae	Cyba.wabr	*Cybaeopsis wabritaska*	Sheet web weavers	2		
Araneidae	Cycl.coni	*Cyclosa conica*	Orb web weaver	1		
Clubionidae	Club.cana	*Clubiona canadensis*	Other hunters	10	17	4
	Club.kast	*Clubiona kastoni*	Other hunters		2	4
	Club.kulc	*Clubiona kulczynskii*	Other hunters	17	20	
	Club.norv	*Clubiona norvegica*	Other hunters	2		
Cybaeidae	Cyba.moro	*Cybaeus morosus*	Sheet web weavers		3	1
Dictynidae	Arge.obes	*Argenna obesa*	Space web weavers			1
	Dict.colo	*Dictyna coloradensis*	Space web weavers			1
	Embl.annu	*Emblyna annulipes*	Space web weavers	1	1	
	Hack.prom	*Hackmania prominula*	Space web weavers		1	
Gnaphosidae	Call.plut	*Callilepis pluto*	Ground hunters	6		
	Dras.negl	*Drassodes neglectus*	Ground hunters	3	3	1
	Gnap.micr	*Gnaphosa microps*	Ground hunters			1
	Gnap.musc	*Gnaphosa muscorum*	Ground hunters	10	11	
	Gnap.parv	*Gnaphosa parvula*	Ground hunters	7	1	
	Hapl.hiem	*Haplodrassus hiemalis*	Ground hunters	2	3	
	Hapl.sign	*Haplodrassus signifer*	Ground hunters	13	1	
	Mica.aene	*Micaria aenea*	Ground hunters	22	4	4
	Mica.cons	*Micaria constricta*	Ground hunters	1		
	Mica.puli	*Micaria pulicaria*	Ground hunters	22	37	39
	Mica.ross	*Micaria rossica*	Ground hunters	15	54	
	Orod.cana	*Orodrassus canadensis*	Ground hunters		2	1
	Serg.mont	*Sergiolus montanus*	Ground hunters			2
	Zelo.frat	*Zelotes fratris*	Ground hunters	4	11	22
	Zelo.puri	*Zelotes puritanus*	Ground hunters		2	4
Hahniidae	Cryp.exli	*Cryphoeca exlineae*	Sheet web weavers	8	2	6
	Hahn.cine	*Hahnia cinerea*	Sheet web weavers	8	1	
	Neoa.agil	*Neoantistea agilis*	Sheet web weavers	20	4	6
	Neoa.magn	*Neoantistea magna*	Sheet web weavers			10
Linyphiidae	Agyn.allo	*Agyneta allosubtilis*	Sheet web weavers		2	
	Agyn.loph	*Agyneta lophophor*	Sheet web weavers	2		
	Agyn.oliv	*Agyneta olivacea*	Sheet web weavers	2		
	Agyn.prot	*Agyneta protrudens*	Sheet web weavers	4		2
	Bath.brev	*Bathyphantes brevipes*	Sheet web weavers	11	2	
	Bath.pall	*Bathyphantes pallidus*	Sheet web weavers	35	242	3
	Cera.brun	*Ceratinella brunnea*	Other hunters	5	4	
	Cera.fiss	*Ceraticelus fissiceps*	Other hunters	15	25	1
	Coll.ksen	*Collinsia ksenia*	Other hunters	2	2	4
	Dipl.bide	*Diplocentria bidentata*	Other hunters	6		
	Dipl.rect	*Diplocentria rectangulata*	Other hunters	2	1	
	Dism.dece	*Dismodicus decemoculatus*	Other hunters	2	3	
	Erig.alet	*Erigone aletris*	Other hunters		1	
	Erig.atra	*Erigone atra*	Other hunters		3	
	Erig.blae	*Erigone blaesa*	Other hunters	1	7	1
	Erig.dent	*Erigone dentigera*	Other hunters	15	4	2
	Erig.dnts	*Erigone dentosa*	Other hunters			1

FAMILY	SPECIES CODE	SCIENTIFIC NAME	GUILD	Canoe Reach 2014	Canoe Reach 2015	Bush Arm 2015
	Eula.arct	*Eulaira arctoa*	Sheet web weavers		1	
	Fred.wilb	*Frederickus wilburi*	Other hunters		2	
	Gnat.tacz	*Gnathonarium taczanowskii*	Other hunters	19	9	
	Gram.angu	*Grammonota angusta*	Other hunters	1		
	Hyps.flor	*Hypselistes florens*	Other hunters	13	1	
	Ince.merc	*Incestophantes mercedes*	Sheet web weavers	1		
	Lept.alpi	*Lepthyphantes alpinus*	Sheet web weavers	67	134	1
	Lept.intr	*Lepthyphantes intricatus*	Sheet web weavers	6	2	1
	Lept.turb	*Lepthyphantes turbatrix*	Sheet web weavers	1	2	
	Macr.mult	*Macrargus multesimus*	Sheet web weavers		1	
	Maso.sund	*Maso sundevalli*	Other hunters		1	
	Merm.tril	*Mermessus trilobatus*	Other hunters	3	1	3
	Micr.mand	*Microlinyphia mandibulata*	Sheet web weavers		1	
	Micr.viar	*Microneta viaria*	Sheet web weavers		3	1
	Neri.dign	*Neriene digna*	Sheet web weavers	2	4	1
	Oedo.alas	*Oedothorax alascensis*	Other hunters	3		
	Oedo.tril	*Oedothorax trilobatus*	Other hunters	6	5	
	Oreo.fili	*Oreonetides filicatus*	Sheet web weavers	8		
	Oreo.recu	*Oreophantes recurvatus*	Sheet web weavers			1
	Oreo.rotu	*Oreonetides rotundus*	Sheet web weavers		1	
	Pele.meng	*Pelecopsis mengei*	Other hunters	4	11	
	Pele.moes	*Pelecopsis moesta*	Other hunters			2
	Pele.scul	*Pelecopsis sculpta*	Other hunters	5	10	9
	Pity.cost	*Pityohyphantes costatus*	Sheet web weavers		1	
	Pity.cris	*Pityohyphantes cristatus*	Sheet web weavers		1	
	Poca.amer	*Pocadicnemis americana*	Other hunters	12	11	
	Poca.pumi	*Pocadicnemis pumila*	Other hunters	3		
	Porr.conv	*Porrhomma convexum*	Sheet web weavers	1		
	Saar.samm	*Saaristoa sammamish*	Sheet web weavers	6	1	
	Scia.trun	*Sciastes truncatus*	Other hunters	7		
	Scot.exse	*Scotinotylus exsectoides*	Other hunters			1
	Scot.pall	*Scotinotylus pallidus*	Other hunters	1		
	Scot.sanc	*Scotinotylus sanctus*	Other hunters	1	1	
	Sisi.mont	*Sisicottus montanus*	Other hunters	6	10	
	Sisi.orit	*Sisicottus orites*	Other hunters	2	4	
	Sisi.pano	*Sisicottus panopeus*	Other hunters		1	
	Spir.mont	*Spirembolus monticolens*	Other hunters	8	16	
	Styl.comp	*Styloctetor compar*	Other hunters		4	9
	Styl.stat	*Styloctetor stativus*	Other hunters	5		
	Symm.mini	*Symmigma minimum*	Sheet web weavers	23	4	
	Tapi.minu	*Tapinocyba minuta*	Other hunters	14	9	4
	Tenu.zela	*Tenuiphantes zelatus*	Sheet web weavers	30	47	
	Tuna.debi	*Tunagyna debilis*	Other hunters	2		
	Walc.atro	*Walckenaeria atrotibialis*	Other hunters	1	1	1
	Walc.cast	*Walckenaeria castanea*	Other hunters		4	1
	Walc.dire	*Walckenaeria directa*	Other hunters	32	42	
	Walc.exig	*Walckenaeria exigua*	Other hunters	42	10	1
Liocranidae	Agro.orna	*Agroeca ornata*	Ground hunters	6	24	15
Lycosidae	Alop.acul	*Alopecosa aculeata*	Ground hunters	135	135	20
	Hogn.fron	*Hogna frondicola*	Ground hunters		6	
	Pard.fusc	*Pardosa fuscula*	Ground hunters	103	2	3

FAMILY	SPECIES CODE	SCIENTIFIC NAME	GUILD	Canoe Reach		Bush Arm
				2014	2015	2015
	Pard.groe	*Pardosa groenlandica*	Ground hunters	1		2
	Pard.lowr	*Pardosa lowriei*	Ground hunters		4	7
	Pard.mack	*Pardosa mackenziana*	Ground hunters	120	57	33
	Pard.moes	*Pardosa moesta*	Ground hunters	118	77	1
	Pard.tesq	*Pardosa tesquorum*	Ground hunters			9
	Pard.wyut	*Pardosa wyuta*	Ground hunters	22	22	1
	Pard.xera	*Pardosa xerampelina*	Ground hunters	743	373	101
	Pira.pira	*Pirata piraticus*	Ground hunters	48	3	2
	Troc.terr	*Trochosa terricola*	Ground hunters	87	264	74
Philodromidae	Phil.alas	*Philodromus alascensis*	Other hunters		7	1
	Phil.cesp	*Philodromus cespitum*	Other hunters		3	
	Phil.onei	*Philodromus oneida*	Other hunters			1
	Phil.pern	*Philodromus pernix*	Other hunters	1		
	Phil.plac	*Philodromus placidus*	Other hunters		1	
	Phil.rufu	*Philodromus rufus*	Other hunters		1	2
	Than.form	*Thanatus formicinus*	Other hunters	3		
	Tibe.oblo	*Tibellus oblongus*	Other hunters		1	1
Phrurolithidae	Phru.bore	*Phrurotimpus borealis*	Ground hunters		1	9
	Scot.pugn	*Scotinella pugnata*	Ground hunters	5	12	
Salticidae	Evar.pros	*Evarcha proszynskii*	Other hunters	4	2	3
	Habr.deco	*Habronattus decorus*	Other hunters			2
	Neon.nell	*Neon nelli*	Other hunters	2	1	
	Pele.flav	*Pelegrina flavipes*	Other hunters	1	1	
Tetragnathidae	Pach.cler	*Pachygnatha clercki*	Orb web weaver	17	1	
	Tetr.labo	*Tetragnatha laboriosa*	Orb web weaver		1	2
	Tetr.vers	*Tetragnatha versicolor*	Orb web weaver	1		
Theridiidae	Enop.intr	*Enoplognatha intrepida*	Space web weavers	1		
	Enop.marm	*Enoplognatha marmorata*	Space web weavers		1	
	Eury.arge	*Euryopis argentea*	Space web weavers	63	8	1
	Eury.fune	*Euryopis funebris*	Space web weavers			3
	Robe.fusc	*Robertus fuscus*	Space web weavers	3	4	
	Robe.vige	*Robertus vigerens*	Space web weavers	4	10	
	Ruga.sexp	*Rugathodes sexpunctatus*	Space web weavers	1		
	Stea.bore	*Steatoda borealis*	Space web weavers		1	
Thomisidae	Xyst.bene	*Xysticus benefactor*	Ambush hunters	4		
	Xyst.brit	*Xysticus britcheri*	Ambush hunters	1		
	Xyst.eleg	*Xysticus elegans*	Ambush hunters	3	1	
	Xyst.elli	*Xysticus ellipticus*	Ambush hunters	13	1	
	Xyst.fero	*Xysticus ferox*	Ambush hunters	1		
	Xyst.luct	*Xysticus luctuosus*	Ambush hunters	1		
	Xyst.mont	*Xysticus montanensis*	Ambush hunters		1	
	Xyst.obsc	*Xysticus obscurus*	Ambush hunters	29	2	
	Xyst.trig	*Xysticus triguttatus*	Ambush hunters		2	
TOTAL				**2152**	**1910**	**468**

Appendix E: **Taxon List for beetles (Coleoptera) identified to species and/or Family**. Total abundance is not standardized by sampling effort

FAMILY	SPECIES CODE	TAXON	Canoe Reach		Bush Arm
			2014	2015	2015
Carabidae			**1934**	**3194**	**1075**
	Agon.cons	*Agonum consimile*	1	0	0
	Agon.corv	*Agonum corvus*	0	1	0
	Agon.cupr	*Agonum cupripenne*	7	10	206
	Agon.sp	*Agonum sp.*	0	0	1
	Agon.grat	*Agonum gratiosum*	0	0	4
	Agon.meta	*Agonum metallescens*	388	211	29
	Agon.muel	*Agonum muelleri*	7	8	69
	Agon.plac	*Agonum placidum*	1	40	0
	Agon.retr	*Agonum retractum*	80	146	4
	Agon.sord	*Agonum sordens*	2	1	0
	Agon.sutu	*Agonum suturale*	0	1	100
	Agon.thor	*Agonum thoreyi*	6	0	0
	Amar.apri	*Amara apricaria*	1	1	0
	Amar.sp1	*Amara sp.1*	0	5	2
	Amar.sp2	*Amara sp.2*	0	0	4
	Amar.sp3	*Amara sp.3*	0	0	1
	Amar.sp4	*Amara sp.4*	0	1	0
	Amar.litt	*Amara littoralis*	12	9	9
	Amar.patr	*Amara patruelis*	0	1	0
	Amar.quen	*Amara quenseli*	1	0	0
	Amar.torr	*Amara torrida*	0	5	0
	Bemb.bima	*Bembidion bimaculatum*	0	1	0
	Bemb.incr	*Bembidion incrematum*	172	25	12
	Bemb.inte	*Bembidion interventor*	0	0	3
	Bemb.kupr	*Bembidion kuprianovii*	4	1	1
	Bemb.nigr	*Bembidion nigripes*	71	86	133
	Bemb.obsc	*Bembidion obscurellum obscurellum*	88	62	19
	Bemb.petr	*Bembidion petrosum petrosum*	0	0	6
	Bemb.plan	*Bembidion planatum*	76	628	59
	Bemb.quad	*Bembidion quadrimaculatum dubitans*	9	25	7
	Bemb.rupi	*Bembidion rupicola*	0	2	1
	Bemb.sord	*Bembidion sordidum*	0	3	7
	Bemb.sp.1	*Bembidion sp.1*	1	0	0
	Bemb.tetr	*Bembidion tetracolum tetracolum*	13	18	1
	Bemb.timi	*Bembidion timidum*	0	0	1
	Bemb.tran	*Bembidion transparens transparens*	0	1	0
	Blet.huds	*Blethisa hudsonica*	12	0	0
	Blet.quad	*Blethisa quadricollis*	1	0	0
	Brad.nigr	*Bradycellus nigrinus*	1	0	0
	Cala.adve	*Calathus advena*	2	3	0
	Cala.ingr	*Calathus ingratus*	173	298	116
	Cara.taed	*Carabus taedatus agassii*	8	24	0
	Chla.lith	*Chlaenius lithophilus*	0	0	27
	Chla.nige	*Chlaenius niger*	1	1	15
	Cici.long	*Cicindela longilabris perviridis*	23	8	1
	Cici.oreg	*Cicindela oregona oregona*	0	16	19
	Cici.repa	*Cicindela repanda repanda*	0	0	3
	Cici.tran	*Cicindela tranquebarica vibex*	3	0	0
	Cyli.terr	*Cylindera terricola imperfecta*	0	0	5
	Cymi.crib	*Cymindis cribricollis*	7	12	5
	Dich.cogn	*Dicheirotrichus cognatus*	1	0	0
	Elap.amer	*Elaphrus americanus*	1	0	0
	Elap.clai	*Elaphrus clairvillei*	3	0	0
	Elap.leco	*Elaphrus lecontei*	0	0	1
	Harp.affi	*Harpalus affinis*	10	30	0
	Harp.sp1	*Harpalus sp.1*	0	1	0
	Harp.sp2	*Harpalus sp.2*	0	4	0
	Harp.sp3	*Harpalus sp.3*	0	4	0
	Harp.sp4	*Harpalus sp.4*	0	2	0

			Canoe Reach		Bush Arm
FAMILY	**SPECIES CODE**	**TAXON**	**2014**	**2015**	**2015**
	Harp.somn	*Harpalus somnulentus*	5	6	0
	Harp.sp.1	*Harpalus sp.1*	18	8	0
	Lori.dece	*Loricera decempunctata*	125	16	0
	Lori.pili	*Loricera pilicornis pilicornis*	11	3	0
	Misc.arct	*Miscodera arctica*	1	0	0
	Nebr.gebl	*Nebria gebleri gebleri*	1	1	0
	Nebr.obli	*Nebria obliqua obliqua*	0	0	1
	Noti.semi	*Notiophilus semistriatus*	0	2	0
	Patr.foss	*Patrobus fossifrons*	0	3	0
	Patr.styg	*Patrobus stygicus*	4	0	0
	Plat.dece	*Platynus decentis*	9	37	15
	Plat.mann	*Platynus mannerheimi*	8	0	0
	Poec.lucu	*Poecilus lucublandus*	0	0	2
	Pter.adst	*Pterostichus adstrictus*	126	287	88
	Pter.ecar	*Pterostichus ecarinatus*	0	0	2
	Pter.herc	*Pterostichus herculaneus*	19	15	4
	Pter.mela	*Pterostichus melanarius melanarius*	16	17	0
	Pter.neob	*Pterostichus neobrunneus*	49	108	0
	Pter.pens	*Pterostichus pensylvanicus*	127	438	1
	Pter.prot	*Pterostichus protractus*	47	99	61
	Pter.ripa	*Pterostichus riparius*	63	18	1
	Scap.angu	*Scaphinotus angusticollis*	42	156	0
	Scap.marg	*Scaphinotus marginatus*	44	154	2
	Scap.reli	*Scaphinotus relictus*	0	0	1
	Synt.amer	*Syntomus americanus*	24	14	6
	Synu.impu	*Synuchus impunctatus*	4	66	20
	Trec.chal	*Trechus chalybeus*	5	1	0
		unidentified adult Carabidae	0	50	0
Staphylinidae			**1042**	**3163**	**267**
		Aleocharinae	510	463	77
	Anth.sp.1	*Anthobium sp.1*	14	0	0
	Eusp.poth	*Eusphalerum pothos*	64	0	0
	Pycn.camp	*Pycnoglypta campbelli*	5	0	0
		Omaliinae	0	92	14
	Oxyp.occi	*Oxyporus occipitalis*	3	0	0
	Anot.niti	*Anotylus nitidulus*	1	0	0
	Anot.sp.1	*Anotylus sp.1*	1	0	0
	Paed.litt	*Paederus littorarius*	2	0	0
	Teta.nige	*Tetartopeus niger*	4	0	0
		Paederinae	0	0	2
	Prot.sp.1	*Proteinus sp.1*	7	0	0
		Proteininae	0	6	0
	Acti.fove	*Actiastes foveicollis*	11	0	0
	Reic.sp.1	*Reichenbachia sp.1*	2	0	0
		Pselaphinae	0	0	2
		Pseudopsinae	0	2	0
	Scap.cast	*Scaphium castanipes*	7	0	1
		Scaphidiinae	0	14	0
		Scaphium sp.	0	2	0
		Scydmaeninae	0	1	0
	Dino.pleu	*Dinothenarus pleuralis*	65	35	2
	Gabr.brev	*Gabrius brevipennis*	4	0	0
	Gabr.pici	*Gabrius picipennis*	1	0	0
	Gabr.shul	*Gabrius shulli*	7	0	0
	Gabr.sp.1	*Gabrius sp.1*	2	0	0
	Gyro.angu	*Gyrohypnus angustatus*	1	0	0
	Hete.conf	*Heterothops conformis*	43	0	0
	Phil.auru	*Philonthus aurulentus*	5	0	0
	Phil.carb	*Philonthus carbonarius*	3	0	0
	Phil.cogn	*Philonthus cognatus*	18	0	0
	Phil.poli	*Philonthus politus*	4	0	0
	Phil.sp.1	*Philonthus sp.1*	4	0	0
	Qued.fulv	*Quedius fulvicollis*	4	0	0

			Canoe Reach		Bush Arm
FAMILY	**SPECIES CODE**	**TAXON**	**2014**	**2015**	**2015**
	Qued.labr	*Quedius labradorensis labradorensis*	17	1	0
	Qued.sp.	*Quedius sp. nov. 1*	2	0	0
	Qued.velo	*Quedius velox*	31	3	0
	Phil.caer	*Philonthus caeruleipennis*	0	2	0
	Onth.cing	*Ontholestes cingulatus*	0	0	1
		Quedius sp.	0	0	1
		Staphylininae	0	0	3
	Sten.asse	*Stenus assequens*	1	0	0
	Sten.aust	*Stenus austini*	1	0	0
	Sten.comm	*Stenus comma*	6	0	0
	Sten.imma	*Stenus immarginatus*	1	0	0
	Sten.juno	*Stenus juno*	10	0	0
	Sten.mamm	*Stenus mammops*	2	0	0
	Sten.scul	*Stenus sculptilis*	2	0	0
	Sten.sp.1	*Stenus sp.1*	4	0	0
	Sten.sp.2	*Stenus sp.2*	4	0	0
	Sten.sp.3	*Stenus sp.3*	3	0	0
		Stenus sp.	0	1	29
		Steninae	0	10	0
	Boli.sp.1	*Bolitobius sp.1*	5	0	0
	Carp.nepi	*Carphacis nepigonensis*	20	0	0
	Isch.fimb	*Ischnosoma fimbriatum*	5	0	0
	Isch.pict	*Ischnosoma pictum*	2	0	0
	Isch.sple	*Ischnosoma splendidum*	13	0	0
	Lord.fung	*Lordithon fungicola*	69	2	0
	Myce.rugo	*Mycetoporus rugosus*	1	0	0
	Myce.sp.1	*Mycetoporus sp.1*	1	0	0
	Niti.tach	*Nitidotachinus tachyporoides*	2	0	0
	Tach.basa	*Tachinus basalis*	4	0	0
	Tach.bore	*Tachyporus borealis*	14	0	0
	Tach.niti	*Tachyporus nitidulus*	26	0	0
	Tach.sp.1	*Tachyporus sp.1*	3	0	0
		Tachyporinae	0	326	8
	Tric.pili	*Trichophya pilicornis*	1	0	0
		unidentified adult Staphylinidae	0	2203	127
Buprestidae			0	2	0
Byrrhidae			0	4	5
Cantharidae			3	17	4
Cerambycidae			17	30	1
Chrysomelidae			16	14	6
Coccinellidae			2	23	1
Corylophidae			5	0	0
Cryptophagidae			114	149	63
Curculionidae			73	91	31
Dermestidae			0	0	1
Dytiscidae			3	3	3
Elateridae			61	308	285
Endomychidae			1	1	0
Eucinetidae			5	17	0
Eucnemidae			0	3	0
Histeridae			0	10	1
Hydrophilidae			4	1	0
Lampyridae			4	10	2
Latridiidae			54	151	72
Leiodidae			13	109	38
Lucanidae			3	0	0
Lycidae			0	0	2
Monotomidae			0	4	0
Mordellidae			1	2	0
Nitidulidae			11	5	16
Oedemeridae			0	0	5
Orsodacnidae			1	0	0
Ptiliidae			1	26	9

FAMILY	SPECIES CODE	TAXON	Canoe Reach		Bush Arm
			2014	2015	2015
Ptinidae			1	1	0
Scarabaeidae			8	27	4
Scirtidae			1	0	0
Scraptiidae			0	40	14
Silphidae			6	161	20
Tenebrionidae			6	282	3
Throscidae			55	343	17
Trachypachidae			4	8	12
Zopheridae			0	1	1
Grand Total			**3449**	**8200**	**1958**