Columbia River Project Water Use Plan

Kinbasket and Arrow Reservoirs Revegetation Management Plan

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

Implementation Year 10

Reference: CLBMON-11A

Study Period: 2017

Okanagan Nation Alliance, Westbank, BC

and

LGL Limited environmental research associates
Sidney, BC

November 22, 2018

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KINBASKET AND ARROW LAKES RESERVOIRS

Monitoring Program No. CLBMON-11A
Wildlife Effectiveness Monitoring of Revegetation Efforts and Physical Works Trials in Kinbasket Reservoir




Final Report

2017

Prepared for

BC Hydro

BC Hydro Generation

Water Licence Requirements
6911 Southpoint Drive
Burnaby, BC

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Cover Photographs:

From left to right: river flowing along the study site established on the northwest side of Bush Arm Causeway, Savannah Sparrow nest at the treatment of Bush Arm Causeway North (*Passerculus sandwichensis*), Thin-legged Wolf Spider (Lycosidae) carrying spiderlings on her abdomen, and vegetation growth on the mound installation with live stakes at the southwest side of Bush Arm Causeway. Photos © Charlene Wood.

EXECUTIVE SUMMARY

The goal of CLBMON-11A is to monitor and assess the efficacy of revegetation efforts and physical works trials to increase the suitability of wildlife habitats in the drawdown zone of Kinbasket Reservoir (i.e., CLBWORKS-1 and CLBWORKS-16). CLBMON-11A is a ten-year sampling program, initiated in 2008, 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, with 2017 representing the penultimate sampling year. A technical review workshop held in 2014 with representatives from BC Hydro, First Nations, contractors, and agencies concluded that most revegetation efforts in the Kinbasket Reservoir have been ineffective, and thus it was not possible to address the management questions as originally stated. Beginning in 2014, we initiated assessment of the effectiveness of woody debris removal to promote the establishment and development of vegetation in the drawdown zone. These physical works trials also included installation of log debris booms to prevent the accumulation of woody debris and debris mounds installed above the full-pool level of the reservoir to reduce inundation-related vegetation mortality and increase within site topographic heterogeneity. These prescriptions, alone or in combination, may function to promote the establishment and development of vegetation in the drawdown zone. The focal taxa selected to study the efficacy of these prescriptions were spiders, beetles, and birds (includes songbirds, grouse, waterfowl, shorebirds, etc.).

Wood debris removal 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. Woody debris removal was implemented at Yellowjacket Creek, Valemount Peatland North, Bush Arm Causeway NW, and Bush Arm Causeway SW. These were supplemented by tethered log booms at Valemount Peatland North and Bush Arm Causeway NW, to attempt to exclude wood deposition during future high-water events. Most of these treatments occurred in 2014, with a follow-up debris removal in 2017 at Yellowjacket Creek. At the Bush Arm Causeway sites, ponds were cleared of wood debris, mounds were created, and live stakes and sedge plugs were planted. A log boom was installed in June 2016 at the Bush Arm Causeway NW treatment site.

We have conducted two years of post-treatment monitoring at the Bush Arm Causeway (BAC-S, BAC-N), three years of post-treatment monitoring at the Valemount Peatland (VP-N), and four years of post-treatment monitoring at Yellowjacket Creek (YJ). Over these years, we documented considerable changes in vegetation cover. The most successful site, in terms of vegetation establishment, was the Valemount Peatland, which is a moister site with a higher organic matter content in soils than other sites (e.g., Packsaddle Cr., Yellowjacket Cr.). Within the areas sampled by pitfall traps and bird transects, treatment areas at all sites have increased in Live Organic Matter cover relative to initial treatment levels.

Birds and arthropod responses have been quite similar. Relative abundance and richness results were mixed for both taxa, however, species-specific shifts and differences in species composition were observed for arthropods and birds since treatment application. For example, arthropod assemblages were significantly different between the treatment and control area at Valemount Peatland North.

Overall, spider and ground beetle species are showing salient responses signalling changes in treatment conditions. For example, in the first few years post-treatment (2014 and 2015), treatment samples were largely dominated by open-habitat ground-running spiders (e.g., *Pardosa moesta*) and bare ground associated beetles species (e.g., *Bembidion planatum, Cicindela tranquebarica,* and *C. longilabris perviridis*). These open habitat species have decreased in abundance since the initial wood removal. In 2016 and 2017 we are observing examples of species turnover, which was expected as open-habitat species are replaced by those more successful in areas with low-lying vegetative cover, which creates more favorable conditions (shade, increased relative humidity, less extreme temperatures). Beetle species that have increased with years since treatment include: *Pterostichus adstrictus, Cicindela oregona, Bembidion quadrimaculatum*, *Platynus mannerheimi*, *Elaphrus clairvillei*, and Seed-eating Ground Beetles (*Amara* spp.). Initial open-habitat ground spider assemblages have declined with year since treatment and species such as *Trochosa terricola* and araneoids (Linyphiidae, Tetragnathidae, and Theridiidae) have replaced them. Given the successful natural revegetation at Valemount Peatland North, and establishment of shrubs and live stakes at the Bush Arm Causeway sites, it is expected that these taxa (and others) will replace more open-habitat species in time.

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. However, the area around Valemount Peatland North, in particular, is suitable for higher densities of a number of breeding bird species. As vegetation establishes on treatment plots, we may see increased use of the drawdown zone by ground or shrub-nesting birds. For example, we expect increases in Savannah Sparrow with increased cover of grasses and other low vegetation in the drawdown zone. Spotted Sandpiper may move into drawdown zone areas cleared of woody debris.

Our ability to address each of the management questions is summarized below. Data collected in the final monitoring year (2018) will clarify conclusions for each management question. In our response to answering the management questions, we have equated “revegetation” to physical works (to better align with the current focus of CLBMON-11A).

Management Question (MQ)	Summary of Key Result
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?	**Summary Findings** 1) An increase in vegetation cover was measured at all treatment plots. Increases in vegetation cover were documented for both control and treatment plots. Likewise, changes in response metrics for birds and arthropods were observed in both treatment and control plots. Thus, we are unable to attribute these changes to a treatment effect. Vegetation and wildlife use in post-treatment years (2014-2017) may be related to lower maximum reservoir levels (<754 m) than in pre-treatment years (2012 and 2013; >754.6 m). 2) Clearing ponds of wood debris in the drawdown zone improves breeding habitat suitability for amphibians (e.g., Western Toad; Hawkes 2017). 3) Spider and beetle species assemblages are distinct between control and treatment plots at most sites and arthropod data shows assemblage turnover, but in both treatment and control areas. Open-habitat, bare-ground associated arthropods have declined in both treatment and control since implementation; species associated with higher levels of vegetation cover have increased in both treatment and control since implementation. 4) Bird richness and diversity increased over time in both treatment and control transects. 5) Control and treatment areas have similar levels of ungulate activity. 6) Debris mounds have the potential for increase in wildlife populations (e.g., small mammal and mesocarnivore populations, Sullivan et al. 2017). **Sources of Uncertainty/Limitations** 1) Data are limited to short-term responses in the absence of full-pool reservoir events. Further, the assessment or revegetation efficacy is limited to site-specific case studies rather than a replicated study. Some uncertainties remain regarding vegetation growth given reservoir operation to normal maximum, whether log booms prevent wood accumulation and whether the wood debris mounds will retain their integrity/stability following inundation/full pool. 2) Overall the study has low power to detect changes in bird use of the drawdown zone due to the small size of plots and limited number of observations in each survey. **Comments** 1) Current data will be supplemented with data from additional treated areas in 2018. The results from KM88 and Pond 12 study sites (added in 2018) will be assessed and a comprehensive time-series analyses forthcoming in 2018 report. 2) Follow-up monitoring is recommended to assess the persistence of revegetation/physical works treatments and long-term effects on wildlife use.

<table>
<tr><th>Management Question (MQ)</th><th>Summary of Key Result</th></tr>
<tr><td>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?</td><td>Summary Findings
1) Our data of ground-dwelling arthropods (spiders and beetles) show that abundance patterns are variable between years, sites, and treatments and seem less related to revegetation or physical works trials, since similar patterns were observed in controls.
Sources of Uncertainty/Limitations
1) Long-term data are lacking for the physical works trials applied in 2014 and 2015, allowing few years of effectiveness monitoring to date.
2) The extent to which treatments explain arthropod abundance compared to other factors is unknown, since controls have exhibited identical changes in arthropod relative abundance. Arthropod catch may be related to inter-annual changes in climatic conditions, reservoir operations, and/or other factors, rather than a specific treatment effect
3) A direct assessment of the availability and abundance/biomass of prey has not occurred, which would require a more focused study on the foraging dynamics and prey preferences of specific predator species.
4) Data collection focuses on ground-dwelling spiders and beetles because of their known habitat specificity and response to initial changes in vegetation cover. Other arthropods (e.g., aerial insects, caterpillars, grasshoppers) may respond differently over the long term.
Comments
1) The general comments for MQ1, above, also apply to this MQ.</td></tr>
<tr><td>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?</td><td>Summary Findings
1) Some arthropod species (e.g., initial bare-ground colonising arthropod species, exotic species, wood-associated species) are expected to decline overtime in treatment plots but there are no suspected negative impacts to wildlife caused by treatment prescriptions. Evidence suggests that amphibians continually use the drawdown zone habitats (CLBMON-37) and breeding activity has been observed in wetlands cleared of wood debris (CLBWORKS-1). There is currently no evidence that revegetation or physical works treatments create sink habitat or increase nest mortality.
Sources of Uncertainty/Limitations
1) The general comments for MQ1, above, also apply to this MQ.
Comments
1) The general comments for MQ1, above, also apply to this MQ.</td></tr>
</table>

<table>
<tr><th>Management Question (MQ)</th><th>Summary of Key Result</th></tr>
<tr><td>4: Which methods of revegetation are most effective at enhancing and increasing the utilization of wildlife habitat in the drawdown zone?</td><td>Summary Findings
1) Overall, removal of wood debris from terrestrial and wetland habitats in the drawdown zone appears to have potential as a habitat enhancement technique. Natural vegetation has established and increased in cover in treatment areas cleared of wood debris and on constructed debris mounds. Increased amphibian activity was reported at the cleared ponds in Valemount Peatland and Bush Arm Causeway NW, in the first breeding season post-wood removal. Little evidence for changes in wildlife utilization at other treatment areas [Yellowjacket, Packsaddle, Bush Arm Causes (south)], thus treatment success is dependent on site characteristics.
2) Preliminary data indicate that cottonwood live stakes have greater survival rates if planted in the fall, compared to spring plantings (Hawkes 2017; fall = 93.5% survival versus spring = 20% survival).
3) Revegetation prescriptions monitored prior to 2014 were largely unsuccessful (low survival). However, high survival of sedge plug treatments is documented from KM88. These plots will only have 1 year of wildlife monitoring (2018)
Sources of Uncertainty/Limitations
1) The response of certain taxa (e.g., small mammals) to increased topographic heterogeneity (mounds) in the drawdown zone is not currently being monitored.
2) In some instances, several techniques were applied in the same area (e.g., BAC-N: wood clearing, mound creation, planting, log boom installation) making it difficult to separate the effectiveness of different treatments. In other instances, sites were repeatedly cleared of wood debris (Yellowjacket and Packsaddle), impeding efforts to assess the response of wildlife to clearing in these areas.
3) The sources of uncertainty/limitations for MQs 1 and 2 , above, also apply to this MQ.
Comments
1) The general comments for MQ1, above, also apply to this MQ.</td></tr>
</table>

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

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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, 2015, and 2016, such as physical works treatments (wood debris removal, wood debris and soil mounds/windrows, and log boom enclosures).

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. The sites monitored at Canoe Reach are abbreviated as follows:

- **VP-N:** Valemount Peatland North
- **YJ:** Yellowjacket Creek

The sites monitored at Bush Arm are abbreviated as follows:

- **BAC-N:** Bush Arm Causeway North (northwest)
- **BAC-S:** Bush Arm Causeway South (southwest)
- **GDF:** Goodfellow 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 the habitats that would potentially be in the drawdown zone if the reservoir did not exist.

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 effectiveness of revegetation efforts at improving habitat for wildlife in the drawdown zone of Kinbasket Reservoir. The terms of reference for CLBMON-11A (BC Hydro 2017) also state that this study's results will aid in more informed decision-making with respect for the need to balance requirements of wildlife that are dependent on 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 drawdown zones.

Monitoring was conducted annually from 2008 to 2012 by CBA (CBA 2009a, 2010b, 2011a,b), and by the Okanagan Nation Alliance and LGL Limited from 2013 to present. 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

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

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, a technical review workshop comprising representatives from BC Hydro, First Nations, contractors and agencies concluded that most revegetation efforts in the Kinbasket Reservoir have been ineffective (BC Hydro 2017), and thus it was not possible to address the management questions as originally stated.

Based on that workshop and recommendations from earlier CLBMON-11A monitoring years (Hawkes et al. 2013), there was a need to adapt the program in a way that would allow a revised set of management questions to be answered relative to the original study objectives and remaining project time.

Starting in 2014, we initiated assessment of the effectiveness of woody debris removal to promote the establishment and development of vegetation in the drawdown zone. In addition to wood removal, we assess the efficacy of log debris booms to prevent the accumulation of woody debris, and debris mounds, which remain above the full-pool level of the reservoir to reduce inundation-related vegetation mortality. These prescriptions, alone or in combination, may function to promote the establishment and development of vegetation in the drawdown zone. The focal taxa selected to study the efficacy of these prescriptions 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. The workplan for 2017 surveys preceded the release of the revised terms of reference, but this report attempts to follow the framework presented in the revised terms for consistency with future reports.

2.0 OBJECTIVES AND MANAGEMENT QUESTIONS

The overarching goal of CLBMON-11A is to monitor wildlife utilization patterns in response to revegetation efforts in 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 to:

1. Assess whether the revegetation prescriptions in the drawdown zone of Kinbasket Reservoir improve habitat for wildlife.
2. Report and provide recommendations in Year 10 (2018) on the effectiveness of the revegetation prescriptions on improving habitat for wildlife in the drawdown.

2.1 Management Questions

To meet the objectives of the monitoring program, several key management questions were developed to help address both the management questions and the study objectives.

The four management questions are:

1. How effective are the revegetation prescriptions at enhancing and increasing the drawdown zone habitat use by wildlife such as birds and amphibians?
2. To what extent does revegetation increase the availability of invertebrate prey (e.g. arthropods) in the food chain for birds and amphibians?
3. How do revegetation prescriptions affect the diversity and abundance for arthropods, amphibians, and birds?
4. Which revegetation method is the most effective at enhancing or increasing the utilization of wildlife habitat in the drawdown zone?

As described in the terms of reference (BC Hydro 2017), 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. Also, as per the terms of reference, testing management null hypotheses are no longer required. This allows for a less rigid and more meaningful statistical approach to be taken that is better suited to experimental, ecological studies.

2.2 CLBMON-11A Study Limitations and Revised Program

The ability to address the above management questions 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 revegetation sites (**Error! Reference source not found.**Appendix A) 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. These changes were formalized in a revised Terms of Reference submission, which was finalized in June 2017 (BC Hydro 2017)

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, and 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). Notably, in 2012 and 2013 Kinbasket Reservoir was filled beyond the normal operating maximum (i.e., > 754.38 m ASL) for the first time since 1997. Since September 2013, water levels have been kept below the operating maximum.

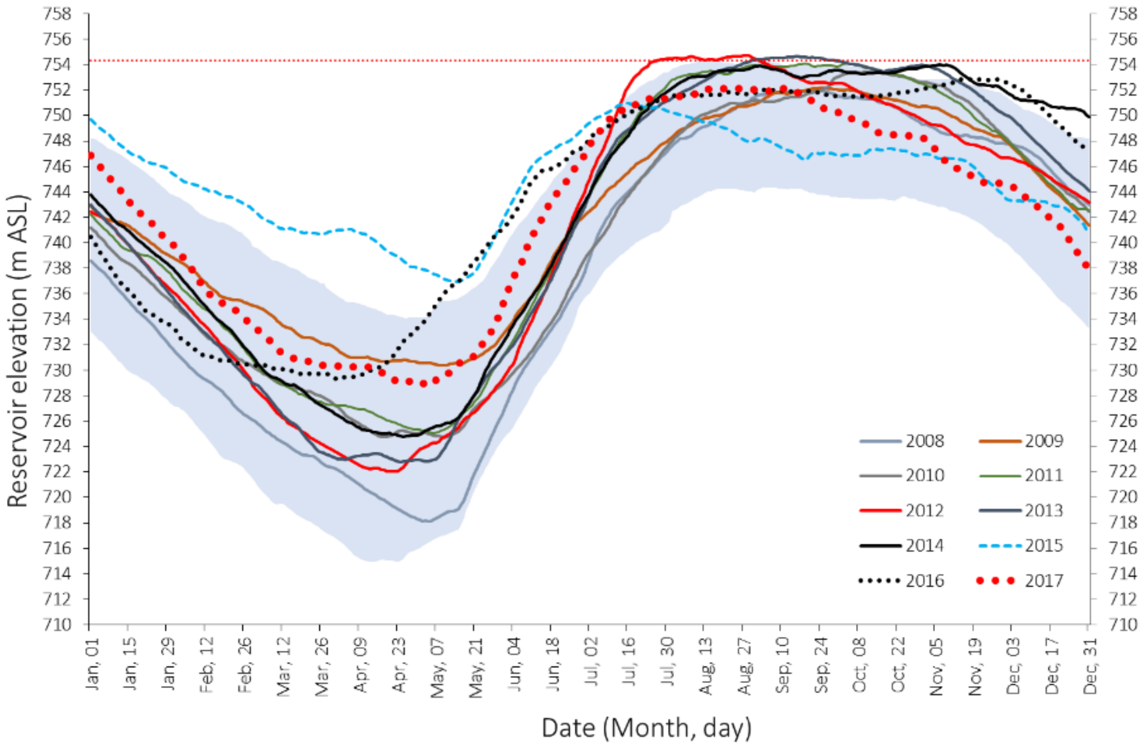

Figure 3-1: Kinbasket Reservoir hydrograph for the period 2008 through 2017. The shaded area represents the 10th and 90th percentile for the period 1976 through 2018; the dashed red line is the normal operating maximum

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.

In 2017, surveys were conducted at four main study sites (Figure 3-2). Two sites were located in Canoe Reach and two sites were located in Bush Arm. Site names and codes are listed in Table 3-2. One exception was that arthropods were collected from the upland forest at Goodfellow Creek as a reference sample in Bush Arm. This site is located adjacent to Bush Arm Causeway South.

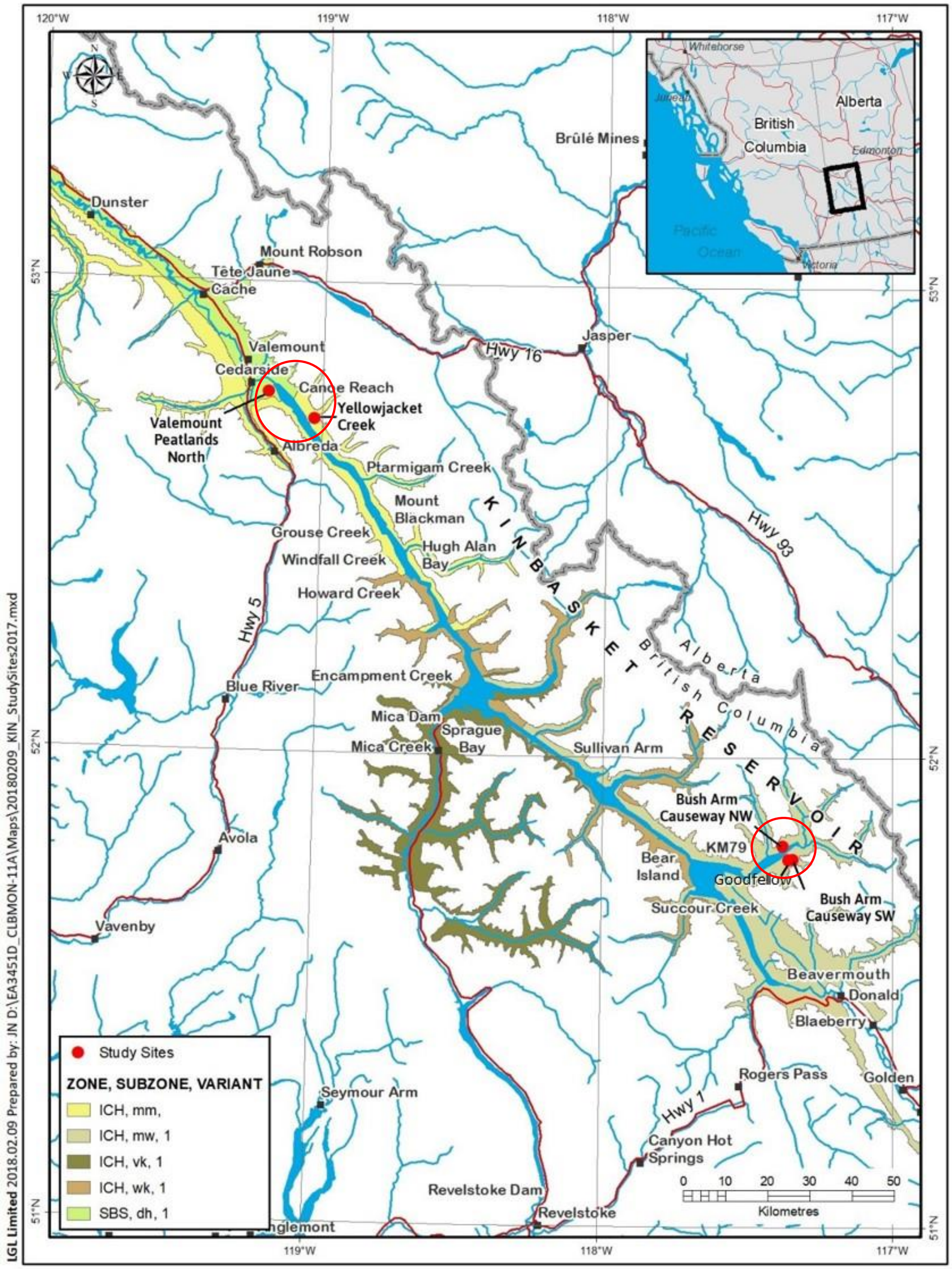

Figure 3-2: Location of Kinbasket Reservoir in British Columbia and locations sampled for CLBMON-11A in 2017 (inside red circles). Refer to Table 3-1 for descriptions of Biogeoclimatic (BEC) zones.

3.6 Physical Works treatments

Large volumes of wood debris covering the drawdown zone of Kinbasket Reservoir were considered a primary factor preventing vegetation establishment and survival (Hawkes et al. 2013b). Thus, it was recommended that woody debris removal be explored as a potential treatment to facilitate natural vegetation colonization and/or vegetation regeneration processes. Following these recommendations, large-scale wood debris removal trials were applied in the upper elevation bands of the drawdown zone of Kinbasket Reservoir.

Treatments were applied in five sites at Canoe Reach and two sites at Bush Arm under CLBWORKS-16 and CLBWORKS-1 (Table 3-2; Hawkes 2016). At Canoe Reach, physical works trials were implemented to remove and exclude wood debris in response to low rates of vegetation survival in the planted plots in the drawdown zone of Kinbasket Reservoir. In 2012, wood debris was removed from Valemount Peatland South, and in 2014 four additional sites were cleared of wood debris at Canoe Reach (Yellowjacket Cr., Valemount Peatland North, Packsaddle Cr. North, and Packsaddle Cr. South). A log boom was also installed at VP-N as a trial to exclude wood accumulation following high reservoir flow events in an attempt to allow vegetation to naturally regenerate in this area. Control plots were established adjacent to wood removal areas, in 2014, to monitor the changes in treatment areas relative to controls over the remaining study years.

Since initial treatment, the study design has been complicated by repeated treatment application and control areas being treated. In 2016, the drawdown zone treatment and control sites at Packsaddle Creek North and South were re-cleared of wood debris. Similarly, the treatment site at Yellowjacket Creek was re-cleared of wood debris immediately prior to wildlife monitoring in 2017 (Figure 3-3), which further compromised the experimental design of the monitoring at Canoe Reach.

Table 3-2: Study sites established at Canoe Reach and Bush Arm of Kinbasket Reservoir. Plot type: treatment (T), control (C), and reference (R); DDZ= drawdown zone, UPL= upland forest. *re-treated plot previously monitored as a treatment, with further wood removal in 2017

	Site	Plot	Plot Description	2017 Surveys
Canoe Reach	Yellowjacket Creek (YJ)	T*	DDZ- woody debris removal (2014, 2017)	Arthropods, Birds, Vegetation
		C	DDZ- woody debris accumulation	Arthropods, Birds, Vegetation
		R	UPL- upland forest	Birds
	Valemount Peatland North (VP-N)	T	DDZ- woody debris removal (2014) & log boom installation	Arthropods, Birds, Vegetation
		C	DDZ- woody debris accumulation	Arthropods, Birds, Vegetation
		DDZ	DDZ- unaltered area adjacent to log-boom	Arthropods
		R	UPL- upland forest	Arthropods, Birds
Bush Arm	Bush Arm Causeway Northwest (BAC-N)	T	DDZ- mound/windrow (2015)	Arthropods, Birds
		C	DDZ- unaltered	Arthropods, Birds
		R	UPL- upland forest	Birds
	Bush Arm Causeway Southwest (BAC-S)	T	DDZ- mound/windrow (2015)	Arthropods, Birds
		C	DDZ- unaltered	Arthropods, Birds
		R	UPL- upland forest	Birds
	Goodfellow Creek (GDF)	R	UPL- upland forest	Arthropods

Figure 3-3: Photo of the Yellowjacket Creek treatment area with machine tracks from wood removal in 2017 immediately prior to arthropod and songbird surveys. Photo taken 12 June 2017 at 11:05 amPhysical Works trials to construct mounds and wind rows and clean ponds of wood debris in the drawdown zone of Kinbasket Reservoir were implemented at Bush Arm Causeway North and South (BAC-N, BAC-S, Table 3-2) in Fall 2015 (Hawkes 2016, 2017). The 2015 project resulted in the construction of seven mounds in two locations, the cleaning of three previously wood-choked ponds in one location, and the removal of wood debris from the surrounding drawdown zone areas. Additionally, these trials were aimed at increasing the topographic heterogeneity of the upper portion of the drawdown zone (i.e., making the flat and uniform surface conditions of the drawdown zone rough and more diverse). This method is proposed to create a diversity of current physical conditions and result in establishment of a diversity of plant species and thus increase site productivity (Polster 2011; Loreau 2010).

To protect areas cleared from wood debris at BAC-N (Table 3-2; particularly the cleared wetlands), a log boom was installed in June 2016. Additional work focused on the planting of live stakes at the mounds at the BAC-S site. The effectiveness of these trials will be evaluated through future years of monitoring under CLBMON-9, CLBMON-37, and CLBMON-11A.

4.0 METHODS

The focal taxa selected for study were ground-dwelling spiders and beetles and all breeding birds. Spiders and beetles were sampled using pitfall traps; birds were sampled via songbird point counts, line transects, and nest searches. The focal taxa align with those sampled under CLBMON-11A in previous implementation years (Wood et al. 2015, 2016, and 2017).

4.1 Revegetation and Physical Works Summaries

For each study site monitored in 2017, a summary of the revegetation and physical works prescription history is provided within corresponding results sections. This information was mainly provided in the CLBWORKS-1 report (Hawkes 2017), with supplemental information drawn from the CLBMON-35 Revegetation Prescription Catalogue for Kinbasket Reservoir (Hawkes et al 2018). The monitoring of revegetation efforts and vegetation compositional analysis is provided under CLBMON-9 (e.g., Hawkes and Miller 2016; Hawkes et al. 2013b).

4.2 Site Conditions

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 (litter), decayed wood, rock, mineral soil, and water. From these measures, “bare ground” was calculated as: 100 – per cent of LOM – per cent of coarse and fine wood debris – per cent of litter. This provides an inverse measure of the amount of cover habitat available to arthropods within sampling areas.

Temperature and Relative Humidity data were collected during arthropod sampling to assess changes in microclimate of treatments overtime. Onset® HOBO® data loggers (U23-002 HOBO Pro v2 External T/RH) were used to measure per cent relative humidity and temperature over the period encompassing arthropod surveys. One logger was deployed at the approximate center of each plot in Canoe Reach and Bush Arm. Data loggers were held in place at the surface of the soil by attaching the base to a pin flag. Locations of all deployed data loggers are shown in maps within Appendix B.

4.3 Terrestrial Arthropods

Species of ground-dwelling (‘epigaeic’) spiders (Araneae) and ground beetles (Coleoptera: Carabidae) are effective focal taxa for monitoring changes in terrestrial habitats. 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. Arthropods are also useful for monitoring small areas, since pitfall collections can be made with approximately 10 m spacing between traps (Samu and Lövei 1995; Bess et al. 2002). Pitfall traps also collect many other arthropod taxa, amphibians, and small mammals, though to a much lesser extent.

The focal taxa align with those sampled under CLBMON-11A in previous implementation years (Wood et al. 2015, 2016, 2017). These are species of spiders (Araneae) and ground beetles (Coleoptera: Carabidae).

4.3.1 Sampling Period

Terrestrial arthropods were sampled in two collection periods at Canoe Reach and Bush Arm in 2017 (Table 4-11). The collection periods were run with a short period of trap closure between sample collections, with a similar sampling period for the two reaches (~10 days at Canoe Reach; ~9 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 to account for the reduced sampling effort in data standardizations.

Table 4-1: Sampling period for terrestrial arthropods for 2017. Number of days (24-hour period) is given for sampling at each location, however this is not adjusted for functional trap time for each trap. CR= Canoe Reach, BA= Bush Arm. Site codes are listed in Table 3-2

Reach	Site	Collection Period	Setup Date	Collection Date	Unadjusted Total Time (Days)
CR	VP-N, YJ	1	**11 & 12-Jun-2017**	16-Jun-2017	4.8
CR	VP-N, YJ	2	**25 & 26-Jun-2017**	30-Jun-2017	5
BA	BAC-N, BAC-S, GDF	1	**14-Jun-2017**	18-Jun-2017	3.9
BA	BAC-N, BAC-S, GDF	2	**27-Jun-2017**	2-Jul-2017	5

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). 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 because it provides excellent insect preservation and is non-toxic to wildlife that may consume the trap contents. 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 Royal British Columbia Museum).

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 previous reports (Wood et al. 2015, 2016, 2017). 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 two study sites within Canoe Reach: Valemount Peatland North (VP-N), and Yellowjacket Creek (YJ). Three treatment types were studied within VP-N (T, C, and R).

In each treatment type in Canoe Reach, nine sampling points were arranged in linear transects as detailed in Figure 4-2. 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.

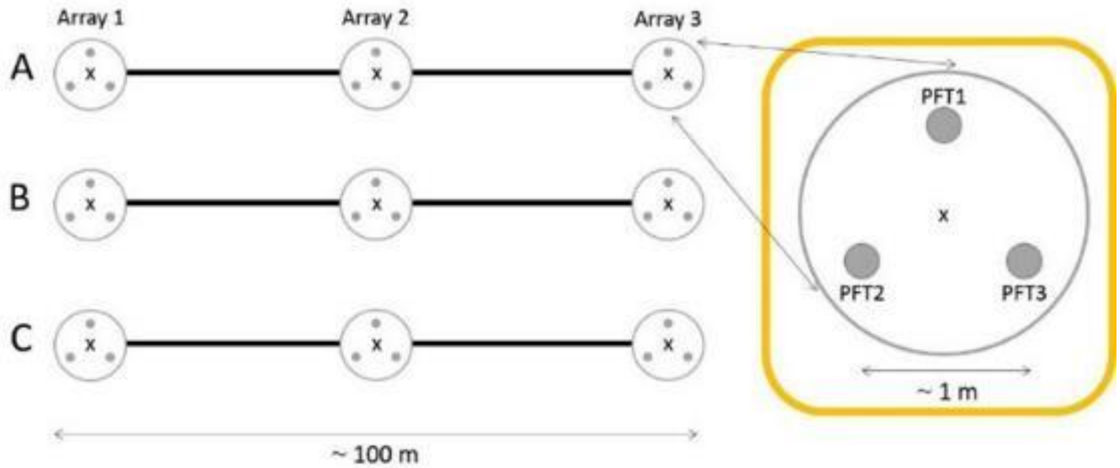

Figure 4-2: Schematic of the experimental design used to sample ground-dwelling arthropods in each treatment at Canoe Reach. Each treatment plot (left) contained nine individual trap arrays (right, yellow), arranged in linear transects. Pitfall arrays contained three pitfall traps (PFT; gray circles) 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 two drawdown zone study sites at Bush Arm in 2017: Bush Arm Causeway NW (BAC-N) and Bush Causeway SW (BAC-S). The upland forest adjacent to BAC-S was also sampled for arthropods as in previous years (Goodfellow Creek Reference). Each delineated 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 (by Charlene Wood, LGL Limited). Dissections of spider and beetle specimens were often necessary to examine traits in genitalia and determine species identity. Beetle classification was based on numerous taxonomic works, including, but not limited to: Arnett and Thomas (2001), Goulet (1983), Lindroth (1961-1969), and Pearson et al. (2006). 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.

4.4 Breeding Birds

4.4.1 Sampling Period

Songbirds and other breeding birds (e.g., shorebirds) were surveyed three times within the regional nesting period identified by Environment Canada (EC 2017), and in concordance with provincial standards (RIC 1999). The regional nesting period identifies the time of year with the highest expected number of breeding bird species for a region, which occurs between mid-late May to mid-July for our study area. In 2017 surveys were completed three times between 11 June and 07 July, at roughly two-week intervals. All surveys commenced at Canoe Reach and ended at Bush Arm. Previous survey years (2015 [see Wood et al. 2016] and 2016 [see Wood et al. 2017]) have been conducted similarly, at the same stations, with surveys between 28 May and 09 July; though only two visits were made in 2015.

4.4.2 Survey Methodology

Survey methodology has been consistent since 2015 (Wood et al. 2016). Line transects were used to survey the drawdown zone (treatment and control areas), while variable-radius point counts were used to survey forest reference sites. All surveys followed established standards (i.e., Bibby et al. 2000; RIC 1999). Surveys began at sunrise and ended within about four hours, to capture the most stable song period (Ralph et al. 1995). Surveys only occurred under favourable conditions (i.e., no heavy wind or precipitation; RIC 1999) to minimize variability in bird behaviour and detection rates related to weather.

Point count surveys occurred from stationary, pre-determined locations. All birds detected were recorded and distances from the observer were estimated to a distance band (i.e., 0-15 m, 15-30 m, 30-45 m, 45-60 m, 60-75 m, and >75 m), with a focus on birds within 30 meters (m) from the observer. A point count survey lasted 6 minutes, within which bird detections were categorized into detection time frames (0-3 minutes, 3-5 minutes, and 5-6 minute).

Line transects were placed within treatment and control areas of the drawdown zone, located relatively close to the shoreline and generally oriented parallel to the reservoir. At Bush Arm, bird surveys were conducted in a straight-line that was laid in the middle of the delineated treatment and control polygons. All line transect surveys were conducted in a straight line between predetermined start and end locations, spaced 100 m apart. The observer traveled the length of the 100 m transect at a speed close to 1.2 km/h, which translated into a five-minute survey (Bibby et al. 2000). All birds detected were recorded and assigned two associated distances: the distance travelled along the transect (0-100 m), and the distance band perpendicular to the transect centreline (0-10 m, 11-25 m, 26-50 m, >50 (Figure 4-3). Although birds at all distances were recorded, the primary focus was on birds within 50 m of the transect centreline. As can be seen in the example provided in Figure 4-3, with bird detections represented by a blue “x”, the Savannah Sparrow (SAVS) would have a 60 m distance along the transect line within the 25-50 m distance band.

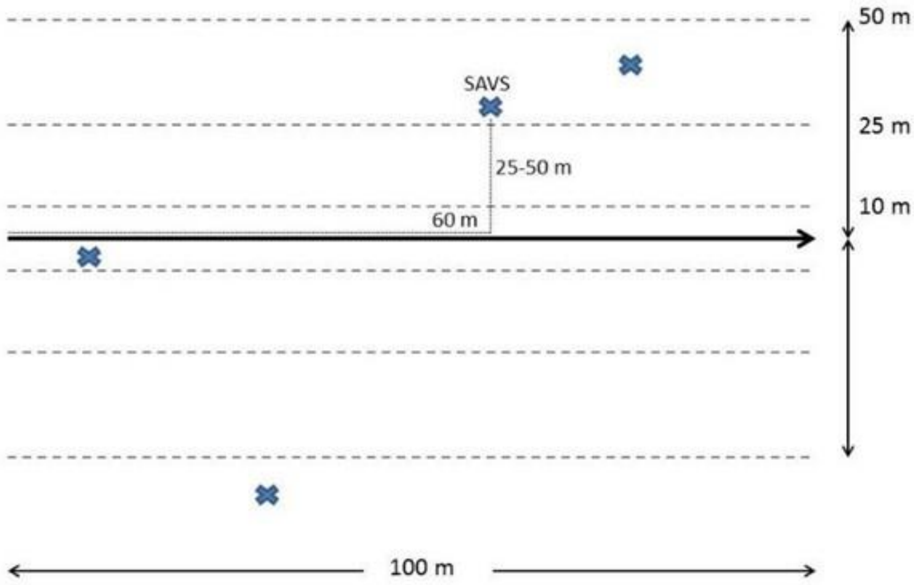

Figure 4-3: Schematic showing the line transect sampling design. The central transect is walked from left to right for 100 m. Birds (represented by blue "x") are recorded from various distance bands. Here an example is given for a Savannah Sparrow (SAVS) observation. Every bird has two associated distances recorded: (1) the distance along the transect to a point perpendicular to the bird (here 60 m), and (2) 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, station number, UTM coordinates, weather (average wind speed, temperature, relative humidity [measured by a Kestrel® 4000 Pocket Weather Meter], cloud cover, presence of precipitation), date, start and end time, and visit number;
2. **Bird observations (sight or sound)**: species, approximate age (adult/ juvenile/ unknown), sex (male/ female/ unknown), location of each detection (distance band and cardinal direction), detection type (song/ visual/ call), and fly-over (yes/ no).

Birds detected outside of survey times or survey locations were recorded as incidental observations. These are informative for generating a complete species list for each site but are not used in analyses.

4.4.3 Sampling and Replication

A total of four sites were surveyed in Kinbasket reservoir; Valemount Peatland North (VP-N) and Yellowjacket Creek (YJ) in Canoe Reach, and Bush Arm Causeway NW and Bush Arm Causeway SW in Bush Arm. At each site, three point-count stations and two line transects (one each in control and treatment plots) were surveyed, for a total of 12 point-count stations and 8 line transects.

4.4.4 Nesting Evidence

At both Canoe Reach and Bush Arm, all treatment and control plots were searched for nesting evidence over the same period as line transect surveys. Nesting evidence provides information on habitat use and suitability to ground nesting and shrub nesting birds in the drawdown zone and is expected to increase in response to successful revegetation and enhancement of the drawdown zone, especially in the upper elevation bands of the reservoir. Given variability between species in the amount of time that can be needed to find a nest, nest searching included noting behaviour that indicated that a nest was close by even when a nest could not be found (e.g., adult carrying food and not flying away, adult feeding a fledgling). Information recorded included species, behaviour, nest stage, nest substrate, number of eggs/offspring, and UTM coordinates. Nests were flagged from a minimum of 10 m away and the distance, bearing and nest substrate was written on the flag (Thomas et al. 1997). Active nests were revisited upon subsequent surveys when possible to assess nest status (success/ failure). Reference sites were not surveyed for nesting evidence, since they offer much different habitat than control and treatment sites, resulting in a markedly different suite of nesting species. Thus, reference site nest records would not be informative to the effectiveness of revegetation and physical works trials in the drawdown zone. Reference sites would also require significantly more effort to nest-search, with suspected differences in nest-finding probability, further limiting the utility of any reference data in comparison with the drawdown zone.

As CLBMON-11A was not intended for robust searching, our data are supplemented with data provided by Cooper, Beauchesne and Associates, Ltd. Bird nest data provided by CBA were collected under CLBMON-36 (e.g., van Oort 2016). All nests occurring within 100 m from treatment and control polygons were provided for Kinbasket Reservoir from 2008 to 2017. Nest searching by CBA occurred in Canoe Reach from 2008 to 2015. This provided data for Valemount Peatland North (VP-N) only (no CBA data from Yellowjacket Creek). Only Bush Arm sites were searched by CBA in 2016 and 2017. Thus, at Canoe Reach, this data only contributes to the initial treatment implementation year and one year post- treatment. It appears that nests were recorded at lower elevations at VP-N than the upper elevation bands targeted by physical works prescriptions and the CLBMON-11A monitoring. Also, nest searching by CBA did not occur in our study site at Yellowjacket Creek. At the Bush Arm Causeway, both sites (BAC-N, BAC-S) were searched quite extensively and provide useful data to supplement LGL Limited's nest searching data collected under CLBMON-11A.

5.0 DATA ANALYSES

Patterns in focal taxon abundance, richness, and composition were assessed within treatments for each site at Canoe Reach and Bush Arm for the 2017 monitoring period. We have adopted this site-specific structure for reporting results to align with the site-specific nature of treatment prescriptions, site conditions, and taxon responses. In some cases, annual trends are presented, however, long-term and inter-annual responses will be examined in detail in 2018.

5.1 Data Standardizations

Arthropod abundance was standardized to the number of individuals collected per trap per day (CPUE per trap per 24 hr sampling period). Prior to analysis of bird species richness and bird abundance, data were constrained by distance from the observer. Within a survey, distance from the observer was constrained to only observations within 30 m at point count stations, and within 50 m from the centreline of line transects. Despite such standardizations, constraints for distance from the observer may still result in the inclusion of some habitat outside of target habitat (i.e., forest habitat adjacent to the drawdown zone). For both point counts and line transects, fly overs – considered detections of species moving over but not using the habitat – were omitted from analysis expect for swallows, swifts and hummingbirds, which forage on the wing and are usually only observed in flight.

5.2 Relative Abundance and Richness

Relative abundance and relative richness of focal taxa were examined through boxplots or bar plots. To aid the reader in interpreting 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).

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

5.3 Species Assemblage Similarity

Similarity of species assemblages were assessed with Venn diagrams using the package 'VennDiagram' in R (Chen 2015). These graphically display the number of unique species in treatment and control plots and the number of species that were shared between plots. The area of each ellipse is proportional to the total number of species observed for that treatment type, allowing for both comparisons of richness and composition (proportion of shared vs unique species).

To test for differences in arthropod species composition between the paired treatment and control samples, we performed a Permutational Multivariate Analysis of Variance (PERMANOVA; Anderson 2001) test for each site. Year was included as a block for all analyses. The Bray-Curtis resemblance measure was used for all tests, which were run with 9999 permutations. PERMANOVAs were performed in the vegan community ecology package (Oksanen et al. 2018). In some cases, post-hoc contrasts were used to explore differences in assemblages between years and treatments using the 'pairwiseAdonis' package (Martinez Arbizu 2017).

5.4 Bird Nesting Evidence

We plotted the locations of all bird nests recorded by LGL under CLBMON-11A and those recorded by CBA within 100 m of our study polygons. Nest data is presented qualitatively as the nest search effort by year and area (e.g., elevation bands targeted for search effort) are not known. Further, nest fate is not known for these locations and cannot be discussed for this reporting period.

6.0 RESULTS

Shifts in arthropod species composition and abundances have been noted over the past three years since implementation of wood removal at study sites in Canoe Reach, (Wood et al. 2015, 2016, 2017), with variable results reported for Bush Arm physical works treatments. Following is a results summary of target taxa (arthropods and breeding birds) post-treatment responses in Canoe Reach and Bush Arm sites. As treatment areas typically did not allow for within-site replication (i.e., for birds the spatial scale too limited), and since site-specific differences exist among the sites (e.g., in location, revegetation prescription, substrate, vegetation community, etc.), we treated each site below as a separate case study.

6.1 Valemount Peatland North – Canoe Reach

Site information for Valemount Peatland North is presented in Table 6-1, Figure 6-1, and Figure 6-2.

Table 6-1 Site description and revegetation prescription information for Valemount Peatland North (VP-N; Table 3-2) in Canoe Reach, Kinbasket reservoir.

<table>
<tr><th>Site Description:</th><th colspan="2">Site information:</th></tr>
<tr><td rowspan="4">Valemount Peatland North is located in Canoe Reach at the northern end of Kinbasket Reservoir. The substrate is primarily organics with a component of open water. The source of water originates from seepage inflows from an existing shrubby wetland just outside the drawdown zone, which makes it both wetter and more nutrient (nitrogen and potassium) rich than other drawdown zone sites within this reach. The soil here is also very high in total organic carbon.</td><td>Reach</td><td>Canoe Reach</td></tr>
<tr><td>UTM</td><td>11U 354041E, 5848139N</td></tr>
<tr><td>BEC Zone</td><td>SBS dh1</td></tr>
<tr><td>Elevation (m)</td><td>Min: 752 Max: 755</td></tr>
<tr><th colspan="3">Treatment Prescription</th></tr>
<tr><td colspan="3">In 2014, woody-debris removal occurred between 752 m and 755 m ASL and a log boom was installed to protect the area from future deposition of woody debris.</td></tr>
<tr><th colspan="3">Summary of Prescription</th></tr>
<tr><td colspan="3">At the treated site within the log boom, vegetation species richness was substantially higher in 2015, both compared to the control and 2014 values. Herbaceous cover also increased more rapidly in the cleared versus non-cleared area between 2014 and 2015. The seepage inflows from an existing wetland likely explains early indications that, following one-year post debris removal, this site is undergoing a rapid recovery toward a functioning semi-wetland community.</td></tr>
</table>

Figure 6-1: Treatment plot at Valemount Peatland North (VP-N T) after initial wood removal in 2014 (top-left) and two years post-treatment in 2016 (top-right), and three years post-treatment in 2017 (bottom). Photo direction of the 2017 photo is looking the opposite direction across the treatment area as the photos in 2014 and 2016. A log boom was installed at this site.

Figure 6-2: Vegetation recovery two months (upper left panel) and 15 months (other panels) following removal of wood debris at the Valemount Peatland North (VP-N) site, Canoe Reach. Upper right panel: nodding beggarticks (*Bidens cernua*) and Douglas' water-hemlock (*Cicuta douglasii*). Lower right panel: marsh cinquefoil (*Comarum palustre*). A log boom was installed at this site.

Substrate composition at Valemount Peatland North (VP-N) has changed little over time, except for a notable increase in vegetation cover at the treatment site (Figure 6-15). Wood debris accumulation appears to have been stable at this treatment area since 2016, with a minor increase in debris accumulation observed for the control area (not protected by a log boom). The variation in vegetation and substrate cover in the three transects of the treatment and control plots at VP-N are characterised in Figure 6-15.

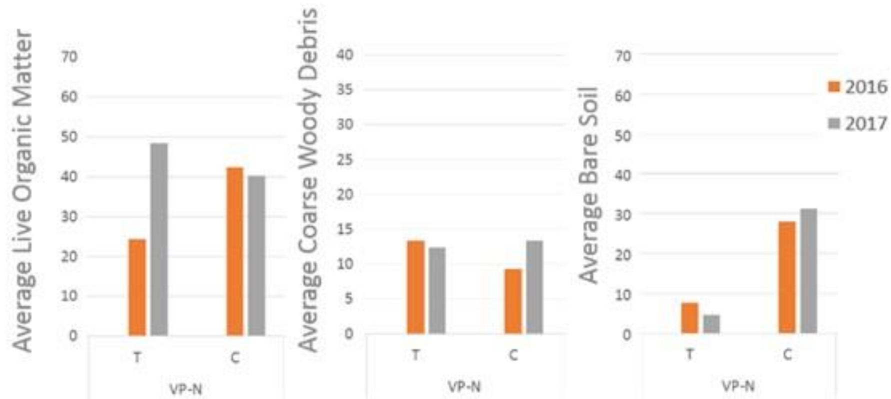

Figure 6-3: Mean per cent cover of vegetation (LOM), coarse wood, and bare soil recorded at treatment (T) and control (C) pitfall trap stations.

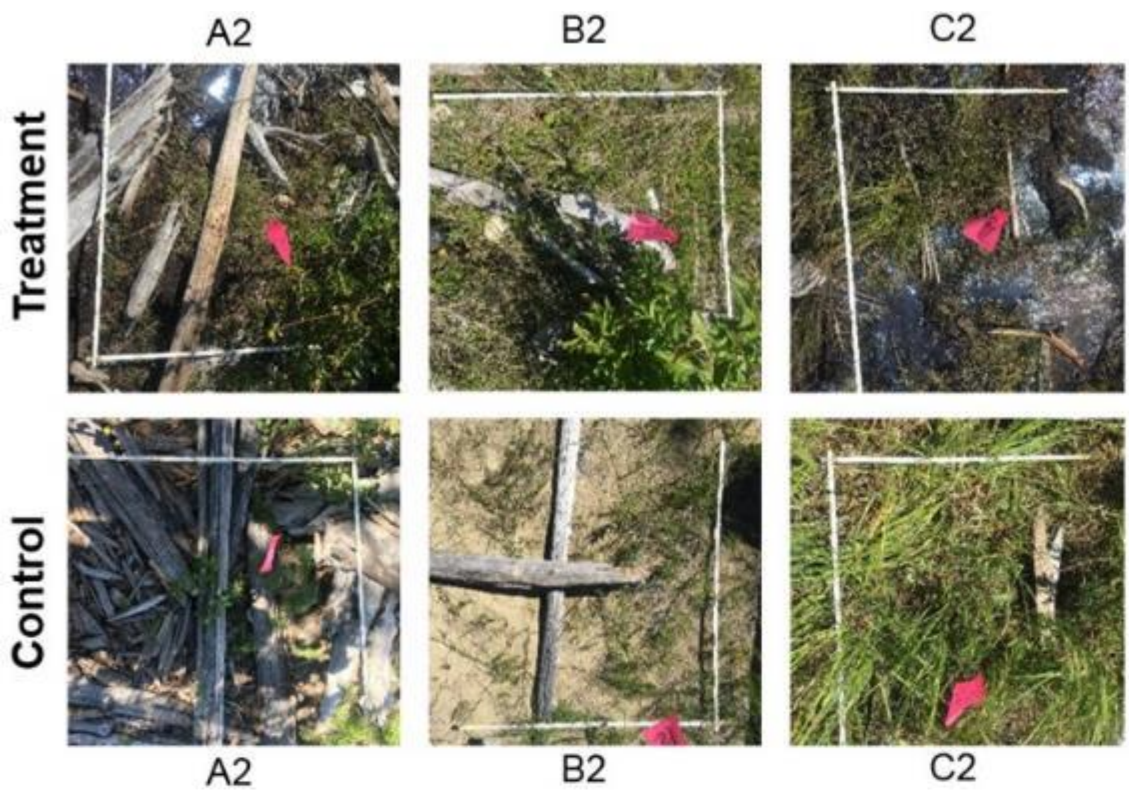

Figure 6-4: Vegetation and substrate cover in the Valemount Peatland North treatment (top) and control (bottom) areas in 2017. Photos show ~1m x 1m of ground cover at central pitfall trap stations (A2, B2, and C2). Note the differences in site moisture, mineral soil, wood debris, and vegetation cover.

6.1.1 Birds

Reference

Thirty-seven species were detected during point counts in reference areas at Valemount Peatland North from 2015-2017. Three point-count stations were established within the upland, open pine-leading forest, roughly 70 m from the shoreline edge and south of the treatment transect. Warbling Vireo (23 observations), Yellow-rumped Warbler (19 observations), Hermit Thrush (18 observations), Chipping Sparrow (17 observations) and American Redstart (17 observations) were the most commonly detected species at all distance bands. When only constrained data are considered, a total of 48 observations of 20 species remain. Fourteen of these 20 species were detected in only one of the three survey years, with only two species (Warbling Vireo and Yellow-rumped Warbler) detected in all three survey years. Yellow-rumped Warbler, Chipping Sparrow, and American Redstart were the most frequently detected species within this site (≥5 observations and detected during at least two years). Strong inter-annual variation in species richness and diversity was noted from 2015-2017 (Figure 6-5). In particular, both metrics were highest in 2016, despite equal sampling effort in 2017 and no obvious change in vegetation community.

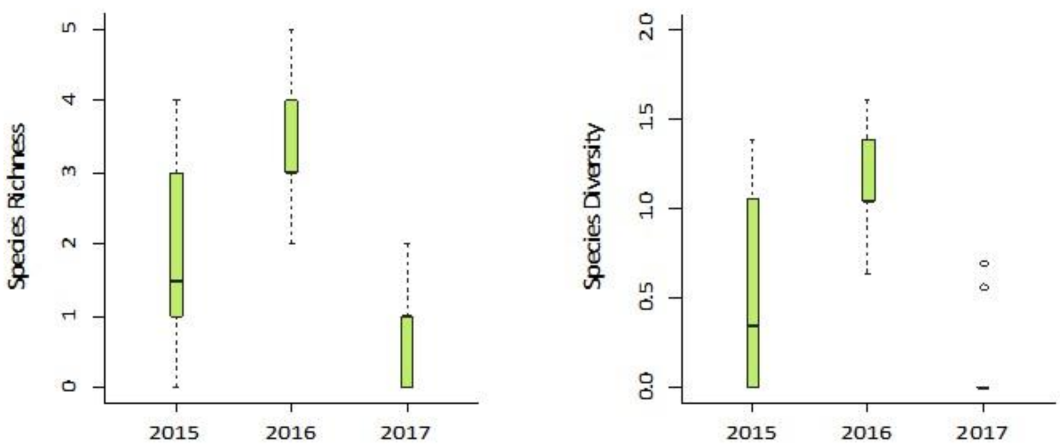

Figure 6-5: Boxplots showing bird species richness (left) and Shannon's diversity index (right) for reference point counts at Valemount Peatland North from 2015-2017.

Treatment and Control

Wood debris removal and log-boom installation occurred during 2014. During the initial year post-treatment (2015), control and treatment transects were equal in richness and diversity (though only one visit was made to the treatment transect that year as a mass exodus of toadlets prevented additional surveys; Figure 6-6). While median richness/diversity values were higher in treatments in 2016, there was no statistical difference between them (overlapping boxes). However, both were significantly higher than in 2015. This trend does not hold in 2017, where median richness and diversity values were significantly higher for the control transect. Both transects had significantly lower richness/diversity values than in 2016, consistent with the results from the reference plot, suggesting that environmental or other external factors were likely driving the annual trend, rather than treatment effects. In 2017 there appeared to be an absence of both open-country (e.g., Savannah Sparrow) species, and forest-edge species (e.g., Chipping Sparrow) from the treatment transect. The cause of this absence is unknown, and it cannot be attributed to any specific factor at this time.

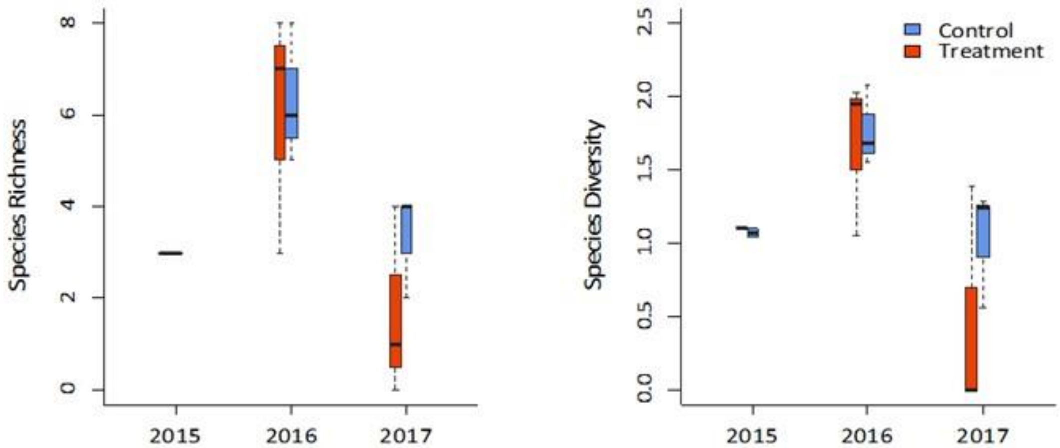

Figure 6-6: Boxplots showing bird species richness (left) and Shannon's diversity index (right) for control (blue boxes) and treatment (red boxes) transects at Valemount Peatland North over three years of surveying. Initial woody debris removal and log-boom installation occurred in 2014.

A total of 30 species have been detected at all distances from both treatment and control transects at Valemount Peatland North. However, a number of these are forest species, detected from beyond the drawdown zone. When data is constrained by distance, the result is 78 observations of 23 species over three years of surveys. Most of the species have been detected from the treatment transect, which also had the highest number of unique species (Figure 6-7). Many of the species detected within both the treatment and control transects are forest species and would have been detected in the ecotone between drawdown zone and forest. However, both transects also had species more typical of the drawdown zone, either as unique or shared species. For example, the open-country Vesper Sparrow, and Western Meadowlark were only detected from the treatment transect (though both only once), while Clay-colored Sparrow, also an open-country species, was only detected from the control. Common Yellowthroat, Lincoln's Sparrow, and Savannah Sparrow were observed from both transects, though all were more abundant along the control transect. Each of these three species were the most commonly detected species in control/treatment transects, with a combined total of 27 out of 34 observations occurring along the control transect. This may be due to the greater shrub cover along and near that transect.

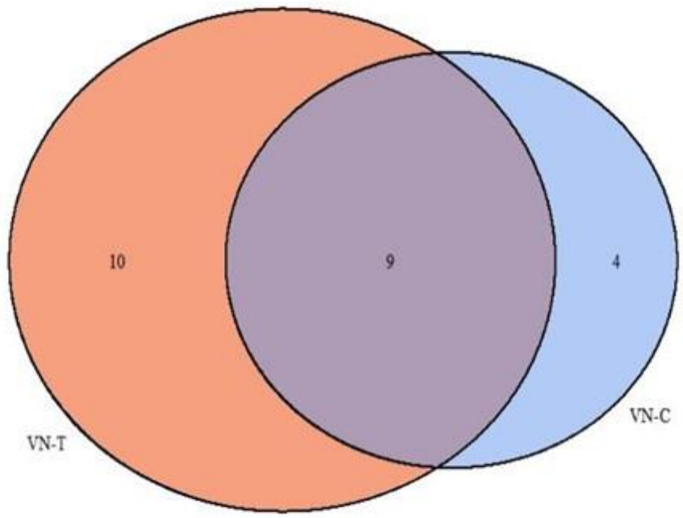

Figure 6-7: Venn diagram showing the number of bird species in the constrained dataset observed at Valemount Peatland North that were unique to control transects (blue area), treatment transects (red area), and shared between the transects (overlapping mauve area). Circles are proportional to the number of observed species.

Nesting Birds

Valemount Peatland North represents one of the main nesting areas for birds in our study areas. A total of 51 nests were in this region, the largest number of any of our study areas (Figure 6-8). These nests were predominantly from sparrows, with Savannah Sparrow (23 nests), Clay-colored Sparrow (12 nests), and Lincoln's Sparrow (8 nests) comprising the majority. Most of these nests were beyond our actual treatment and control polygons, and many of these nests were detected prior to treatment application in both treatment and control areas (note: search effort may have varied by year and location). There are Clay-colored Sparrow nests (2) from within the treatment polygon, and both Clay-colored and Lincoln's Sparrows nest within, or very close to the edge, of the control polygon. Savannah Sparrows, while the most abundant breeding species by number of nests in the area, appear to nest slightly farther from the edge of the upland habitats. This may be due to habitat preferences, or predator avoidance strategies. It is clear that this area supports relatively high breeding bird activity. Sandpiper breeding activity is sparse in this area, though Killdeer nests (two) have been documented near the treatment area, in what were rockier, less vegetated sections. The upland edge also supports a number of breeding species not characteristic of the drawdown zone (e.g., Dusky Flycatcher, American Redstart, and Cedar Waxwing). These species may occasionally utilize areas in or near the drawdown zone to forage, especially where shrubbier vegetation exists.

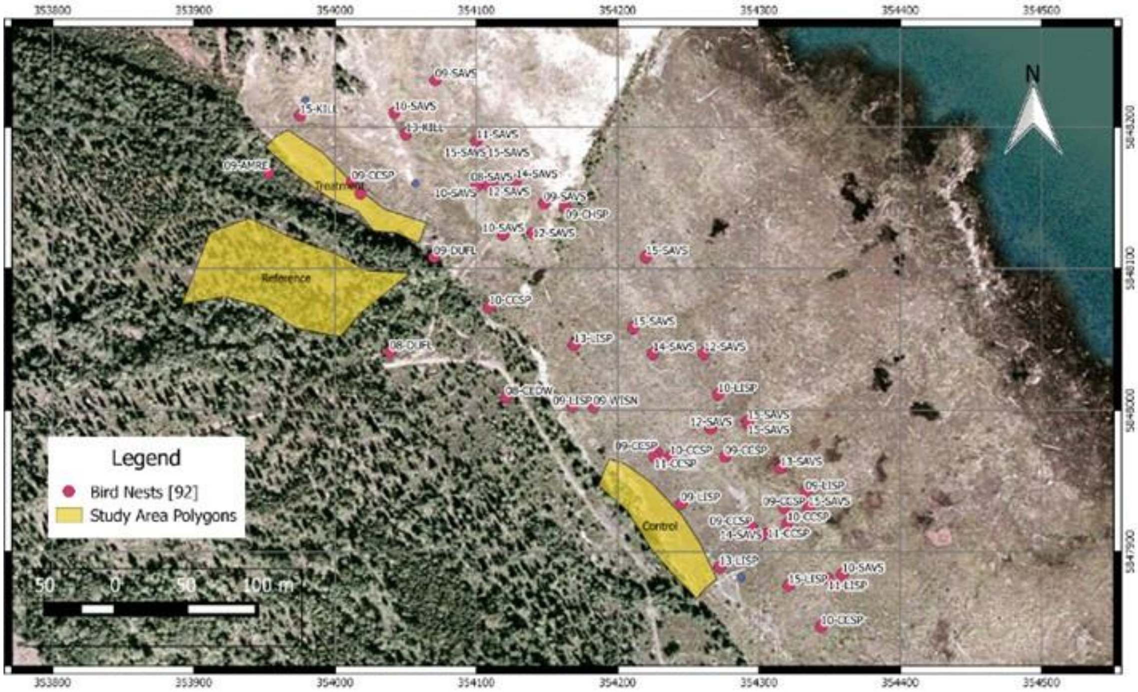

Figure 6-8: Locations of treatment, control and forest reference polygons and detected bird nests at Valemount Peatland North in Canoe Reach, Kinbasket reservoir. The first two numbers of each nest code signify the year of nest detection (2008 - 2017)

6.1.2 Terrestrial Arthropods

Despite an initial increase in relative abundance of spiders and beetles in 2016, the catch was similar for 2014 and 2017 years (Figure 6-9). That the same pattern in relative abundance was shown for both the treatment and control plots suggests that the increase in arthropod catch was related to inter-annual variation, changes in vegetation and/or substrate characteristics, rather than a specific treatment effect. Relative abundance of spiders and beetles appeared similar for paired treatment and control areas within each year.

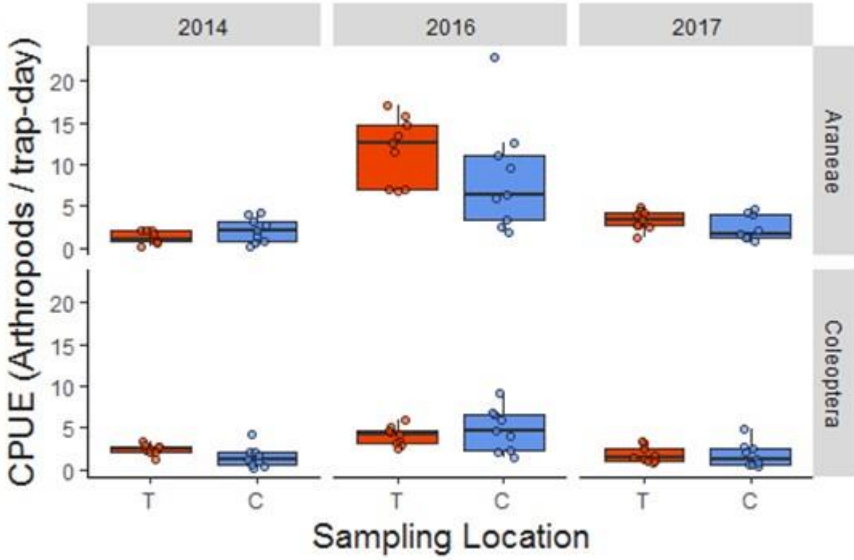

Figure 6-9: Spider and beetle catch per unit effort (CPUE) for pitfall traps by year and treatment type at Valemount Peatland North. Points for each array (collections pooled) are overlaid on boxplots, jittered to avoid overlap.

Over the three years of sampling at Valemount Peatland North, we have identified 106 species of arthropods from the treatment area and 101 species from control area. In each year of sampling, species richness of the treatment area was similar to control richness (Figure 6-10; overlapping 95% confidence intervals). Spider species richness appeared to increase for both treatment and control plots in 2016 and 2017, rivalling the richness observed in the upland reference forest. Beetle species richness was similar for reference, control, and treatment areas in 2014, but likewise richness increased for the drawdown zone areas (control and treatment).

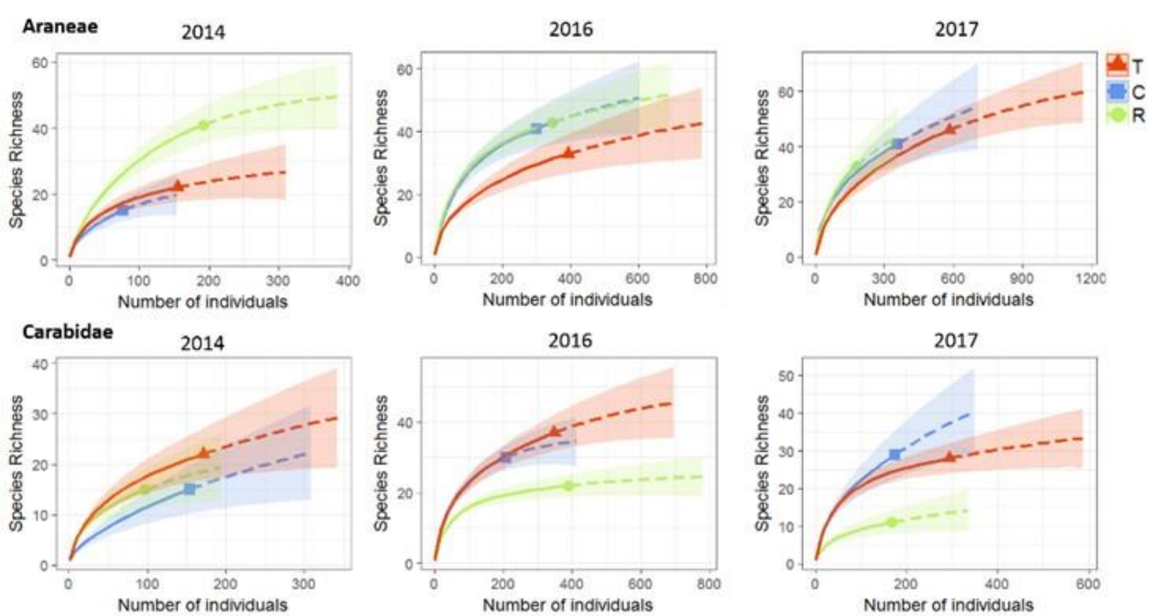

Figure 6-10: Spider and Ground beetle species richness by habitat type and year at Valemount Peatland North. Richness is standardized per individual collected. Shaded regions indicate the 95% confidence interval around each richness curve.

Points are given at the observed species richness value for each habitat type, followed by extrapolated species richness (dashed line). Solid line = interpolated species richness. Habitat types: T= treatment, C= control, R= upland reference

Over all years combined, 66% of species were common between the Valemount Peatland control and treatment plot (68 species found in both areas). Despite the large portion of species shared, arthropod assemblages were significantly different between the treatment and control area (Table 6-2), when analyses were blocked by year.

Table 6-2: Results of PERMANOVA test for differences in arthropod assemblages by treatment type (Treatment vs Control) at Valemount Peatland North, blocked by year. Analysis was run with 9999 permutations and Bray-Curtis Dissimilarity

	Df	SS	MS	F	R^2	p-value
T vs C	1	0.7937	0.79372	2.691	0.0492	0.0017**
Residuals	52	15.3377	0.29496		0.9508	
Total	53	16.1314			1	

Across years, arthropod composition was similar between treatment and control samples for both spiders (Araneae) and Ground beetles (Carabidae), owing to a large portion of shared species relative to unique species in each sampling area (Figure 6-11). However, although the number of shared spider species was similar for 2016 and 2017, the treatment plot was found to have twice as many unique species in 2017 as the previous year. The converse was true for Ground beetles, which had half as many unique species in 2017 as in 2016. Such changes in species identities within plots over time may signal species turnover in response to temporal changes in environmental factors.

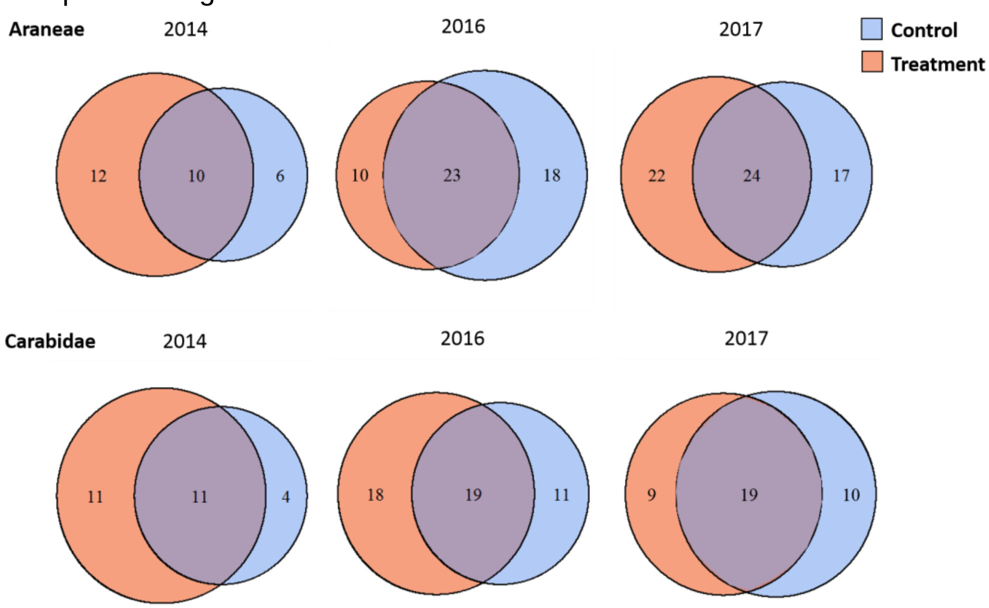

Figure 6-11: Venn diagrams of species composition for target arthropod taxa by year and habitat type at Valemount Peatland North. Number of species unique to each habitat type is given for control and treatment plots, with the number of shared species provided in the overlapping regions. Extent of overlap is proportional to the assemblage similarity between habitats.

Examining the change in relative abundance of species in treatment samples since wood removal revealed some trends in species turnover that are consistent with vegetation changes documented in Figure 6-1. Two species that were most abundant in 2014, *Agonum metallescens* and *Pardosa moesta*, are associated with open sites with low vegetation cover (*Carex*, *Equisetum*, depressed grasses; Larochelle and Larivière 2003) and have steadily decreased since wood removal. Coinciding with this decrease has been the increase in other species; for example, the ground beetles *Pterostichus adstrictus*, *Platynus mannerheimi*, and *Elaphrus clairvillei* have all shown a pattern of increase since 2014. These species are associated with vegetated open or closed sites, rather than bare ground (Larochelle and Larivière 2003). The natural history of *E. clairvillei* states a preference for "ground shaded by tall plants, shrubs, or trees; soft, wet, muddy, rarely saline soil, rich in organic debris, sometimes with bare spots surrounded by vegetation". While the shrubs and tree seedlings present at the VP-N treatment are still quite young, we anticipate this species to increase in relative abundance as the site becomes more shaded by established shrubs and saplings.

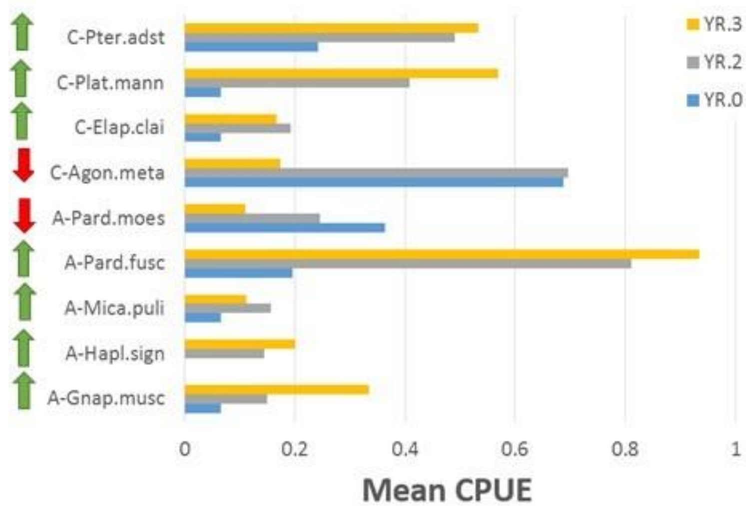

Figure 6-12: Relative abundance (adult catch per trap-day) of select spider and beetle species from the treatment area by years since wood removal at Valemount Peatland North. Arrows are provided for ease of interpretation, where abundance increase since wood removal is shown in a green, upward facing arrow. Declining abundance since treatment is shown by a red, downward facing arrow. A- Araneae, C- Coleoptera

For inference on spider species changes over time, we consulted the provincial expert, Dr. Robb Bennett (pers. comm., February 20, 2018). In general, dry conditions do not favour the majority of spiders, so spider faunal changes likely reflect the relative increase in more hospitable habitat (e.g., more cover, cooler, habitat with increased relatively humidity), relative to the open exposure of the 2014 treatment habitat. The two *Pardosa* species shown in Figure 6-12 are very common throughout the Nearctic region. *P. moesta* is especially dominant in pitfalls traps sampling open habitat, may be one of the lycosids most tolerant of completely open, extreme habitats. This could be due to lesser competitive advantage in more hospitable habitats, due to its relatively small size. Thus, as habitats transition to increased vegetation cover, other larger, better competitors, such as *P. fuscula* seem to replace *P. moesta*.

Similarly, three other three species have increased since wood was cleared from the treatment area, *Micaria pulicaria*, *Haplodrassus signifier*, and *Gnaphosa muscorum*. These species all belong to the family Gnaphosidae (Ground spiders), which are probably responding to the increasingly hospitable habitat. If forest cover or at least shrubs are able to re-establish, these species will likely all drop out and be replaced by species more tolerant of shady, cool summer conditions (Dr. Robb Bennett, pers. comm., February 20, 2018). For example, *Trochosa terricola* (Lycosidae) would be expected to increase in abundance with increased shrub/tree cover, along with greater abundance and diversity of spiders in the families Linyphiidae, Theridiidae, and Araneidae.

6.2 Yellowjacket Creek – Canoe Reach

Site information for Yellowjacket Creek is presented in Table 6-3, Figure 6-15, Figure 6-14, and Figure 6-13.

Table 6-3 Site description and revegetation prescription information for Yellowjacket Creek (YJ; Table 3-2) in Canoe Reach, Kinbasket reservoir.

<table>
<tr><th>Site Description</th><th colspan="3">Site information</th></tr>
<tr><td rowspan="4">Yellowjacket Creek is located in Canoe Reach at the north-eastern end of Kinbasket Reservoir. The substrate composition is primarily mineral soil and rock with areas of natural seepage in the control site.</td><td>Reach</td><td colspan="2">Canoe Reach</td></tr>
<tr><td>UTM</td><td colspan="2">11U 361503E, 5841055N</td></tr>
<tr><td>BEC Zone</td><td colspan="2">ICH mm</td></tr>
<tr><td>Elevation (m)</td><td>Min: 752</td><td>Max: 755</td></tr>
<tr><th colspan="4">Treatment Prescription</th></tr>
<tr><td colspan="4">A treatment prescription was developed in early 2010 (Keefer and Moody 2010). Planting occurred in 2010 and no other year (KES 2010). Woody-debris removal occurred in 2014 and again in 2017 along the primary zone of deposition between 752 m and 755 m ASL.</td></tr>
<tr><th colspan="4">Summary of Prescription</th></tr>
<tr><td colspan="4">An opposite trend than expected was observed between treated (wood debris removal) and non-treated (control) sites at Yellowjacket Creek, where revegetation of the treated area lagged behind that of the non-treated area. The higher productivity within the non-treated area with woody debris compared to the treated area cleared of woody debris was likely due to differences in soil substrate and moisture between the areas. The non-treated area had moist to wet organic soils located underneath the woody debris, owing to natural seepage in this location, whereas the treated area substrate was drier, rockier (gravel-cobble), lower in organic content, and relatively unproductive.</td></tr>
</table>

Figure 6-13: Vegetation growing through wood debris at Yellowjacket Creek control (left), and overview of the control site (right). Left: 21 June 2015; right: 12 June 2017

Figure 6-14: Treatment plot at Yellowjacket Creek (YJ T) after initial wood removal in 2014 (top), and post treatment in 2015, 2016, and 2017 (re-treatment). A log boom was not installed at this site. Note the bare ground in 2017 was related to vehicle disturbance from unanticipated wood removal immediately prior to sampling.

Substrate composition at Yellowjacket creek has changed slightly over time (Figure 6-15). Despite re-treatment (wood removal) at the treatment area in 2017, we measured an increase in vegetation cover, particularly due to increased growth of graminoids in the lowest elevation band monitored (~750 m ASL). We also measured the decrease in wood debris and increase in bare soil associated with the wood removal activities in the treatment area in this year. Substrate was more variable within the control area, with a decrease in observed LOM in 2017 (relative to previous years), which coincided with both and increase in wood debris accumulation and bare soil.

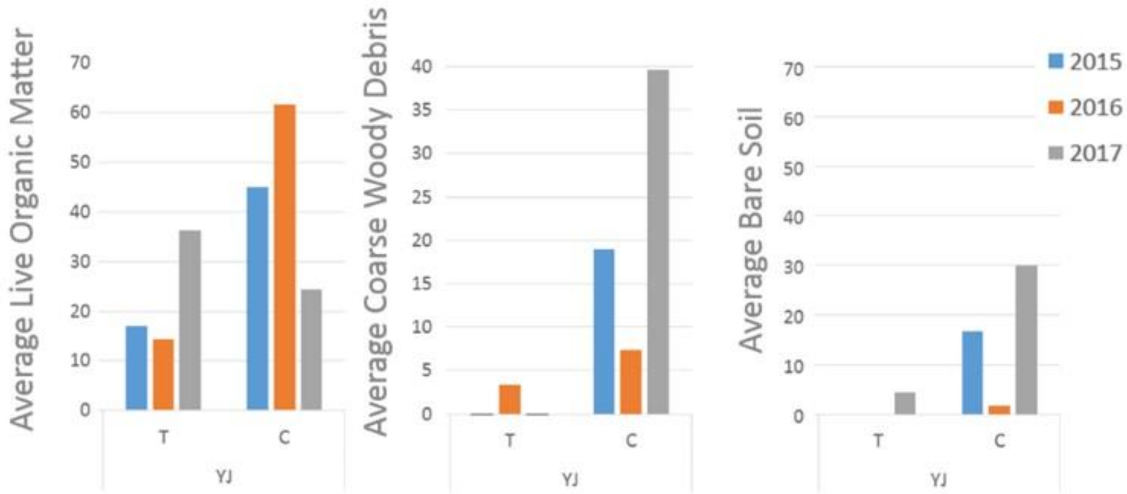

Figure 6-15: Mean per cent cover of vegetation (LOM), coarse wood, and bare soil recorded at treatment (T) and control (C) pitfall trapping stations at Yellowjacket Creek.

6.2.1 Birds

Reference

A total of 25 species were detected during point counts in reference areas at Yellowjacket Creek from 2015-2017. Three point-count stations were established within the upland, coniferous and riparian forest at Yellowjacket Creek, roughly 75-150 m from the shoreline edge. Swainson's Thrush (27 observations), Warbling Vireo (20 observations), and Yellow-rumped Warbler (14 observations) were the most commonly detected species at all distance bands. When only constrained data are considered, a total of 26 observations of 13 species remain. Nine of these 13 species were detected in only one of the three survey years. There were no species detected in all three survey years. Warbling Vireo, Golden-crowned Kinglet, Swainson's Thrush and American Redstart were the most frequently detected species within this site (≥2 observations and detected during at least two years). Strong inter-annual variation in species richness and diversity was noted from 2015-2017 (Figure 6-16). In particular, both metrics were highest in 2016, despite equal sampling effort in 2017 and no obvious change in vegetation community.

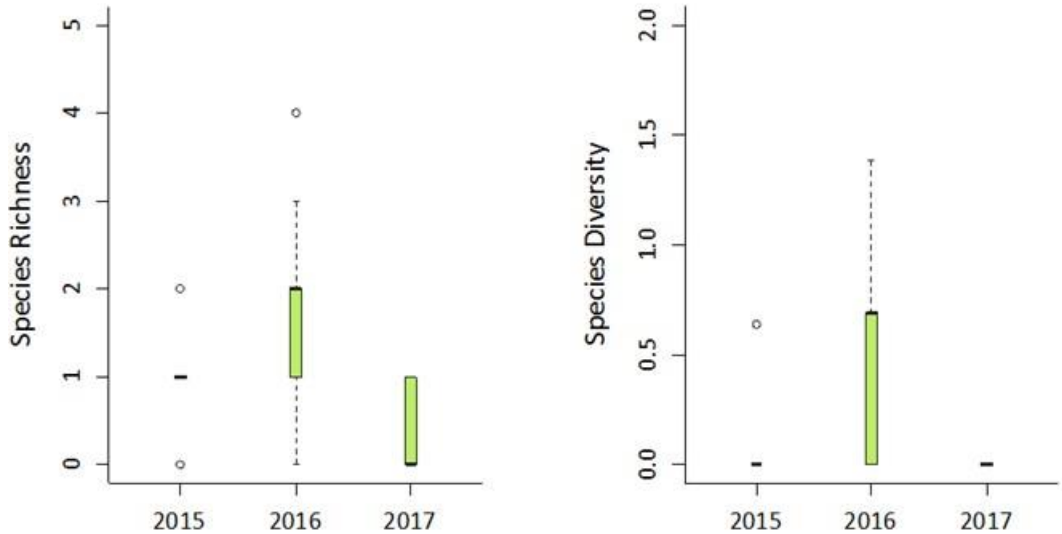

Figure 6-16: Boxplots showing bird species richness (left) and Shannon's diversity index (right) for reference point counts from 2015-2017 at Yellowjacket Creek.

Treatment and Control

The assessment of treatment and control transects at Yellowjacket Creek is confounded by the differences in soil type/moisture regime. They are further confounded by a re-application of woody debris removal in the treatment plot immediately preceding bird surveys in 2017 (the original application occurred in 2014). During the first two years of post-treatment monitoring (2015 and 2016), the control had significantly greater richness and diversity than the treatment (Figure 6-17). This trend does not hold in 2017, where median richness and diversity values were equal for treatment and control transects. The pattern of increased richness/diversity in 2016 is consistent with the results from the reference plot, suggesting that environmental or other external factors were likely driving the trend, rather than treatment effects. That both the control and treatment transects declined in richness/diversity in 2017 also suggests that the re-application of woody debris removal was not the cause of this decline.

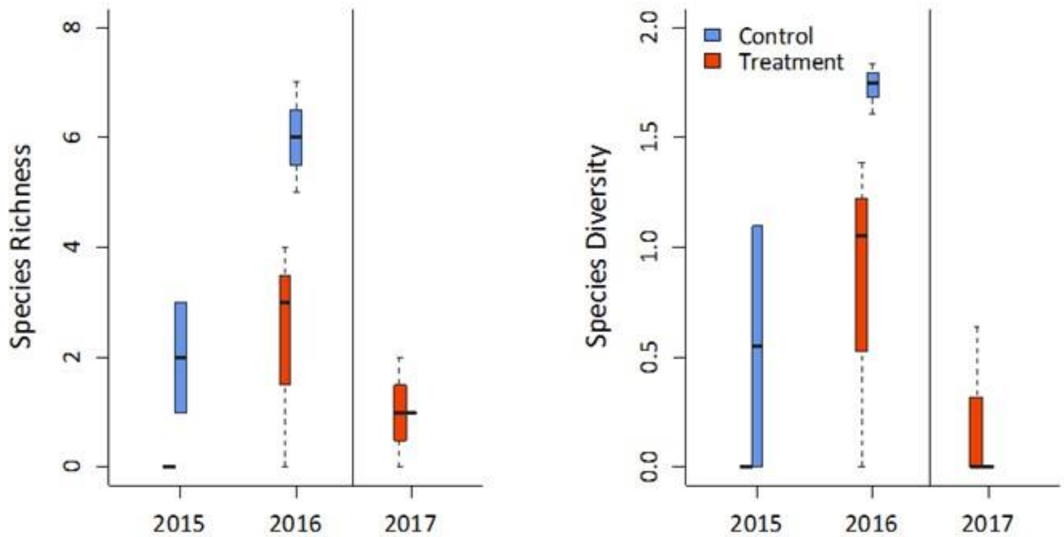

Figure 6-17: Boxplots showing bird species richness (left) and Shannon's diversity index (right) for control (blue boxes) and treatment (red boxes) transects at Yellowjacket Creek over three years of surveying. Initial woody debris removal occurred in 2014, with a follow-up application in 2017 (black vertical line) immediately prior to the commencement of bird surveys.

A total of 21 species have been detected at all distances from both treatment and control transects at Yellowjacket Creek. However, a number of these are actually forest species. When data is constrained, the result is 42 observations of 14 species over three years of surveys. Most of the species have been detected from the control transect, which also had the highest number of unique species (Figure 6-18). Many of the species detected within the control transect are forest species and would have been detected in the ecotone between drawdown zone and forest, though several (e.g., Lincoln's Sparrow, Common Yellowthroat) would be attracted to the wetter, more vegetated conditions present in that transect. Common Yellowthroat was only detected from the control transect, while eight of eleven Lincoln's Sparrow observations were in this transect. Relatively few species were detected in the treatment transect potentially owing to its drier, gravel/cobble substrate with lower vegetation cover. Those conditions may be more attractive to Spotted Sandpiper, which was only detected from the treatment transect, with observations in both 2016 and 2017. Overall, Lincoln's Sparrow was the most commonly observed species in these transects, with most other species having only one to several observations each.

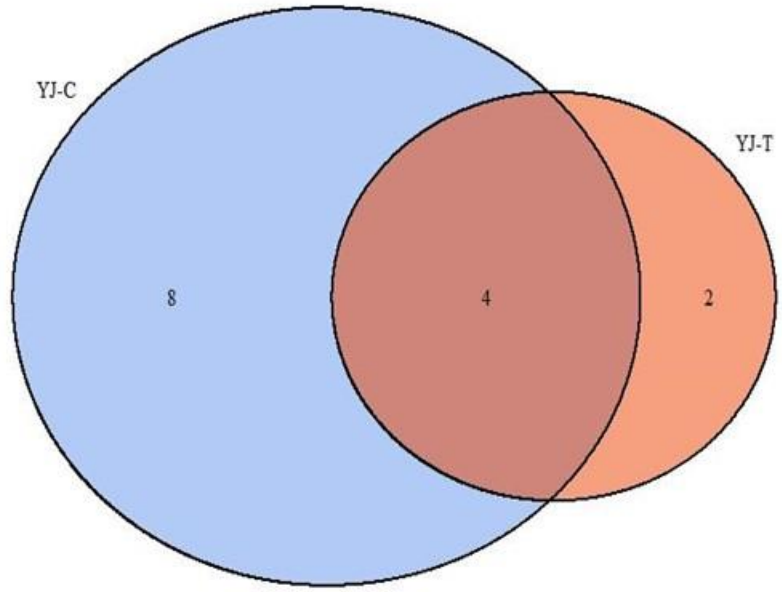

Figure 6-18: Venn diagram showing the number of bird species in the constrained dataset observed at Yellowjacket Creek that were unique to control transects (blue area), treatment transects (red area), and shared between the transects (overlapping mauve area). Circles are proportional to the number of observed species.

Nesting Birds

Few bird nests have been discovered at Yellowjacket Creek during 2015-2017 surveys (Figure 6-19). One Spotted Sandpiper was located almost mid-way between the control and treatment plots (and thus in neither) in 2017. In 2015, very recently fledged Spotted Sandpiper chicks (Spotted Sandpipers are precocial and leave the nest about 24 hours after hatching) were discovered in virtually the same location. The only other physical nest was a Cedar Waxwing discovered near the edge of the control plot, about 3 m high in a willow. Finally, a recently fledged Tennessee Warbler chick was observed being fed by an adult in a willow along the edge of the drawdown zone. Thus, shrubby vegetation along the edge of the control plot seems likely to provide some nesting opportunities for certain species, or at least foraging opportunities for species that have nested in nearby upland locations, while more open habitat provides nesting potential for species such as Spotted Sandpiper at this location. Woody debris removal may encourage Spotted Sandpiper nesting, and this species should continue to be looked for in the treatment area in 2018.

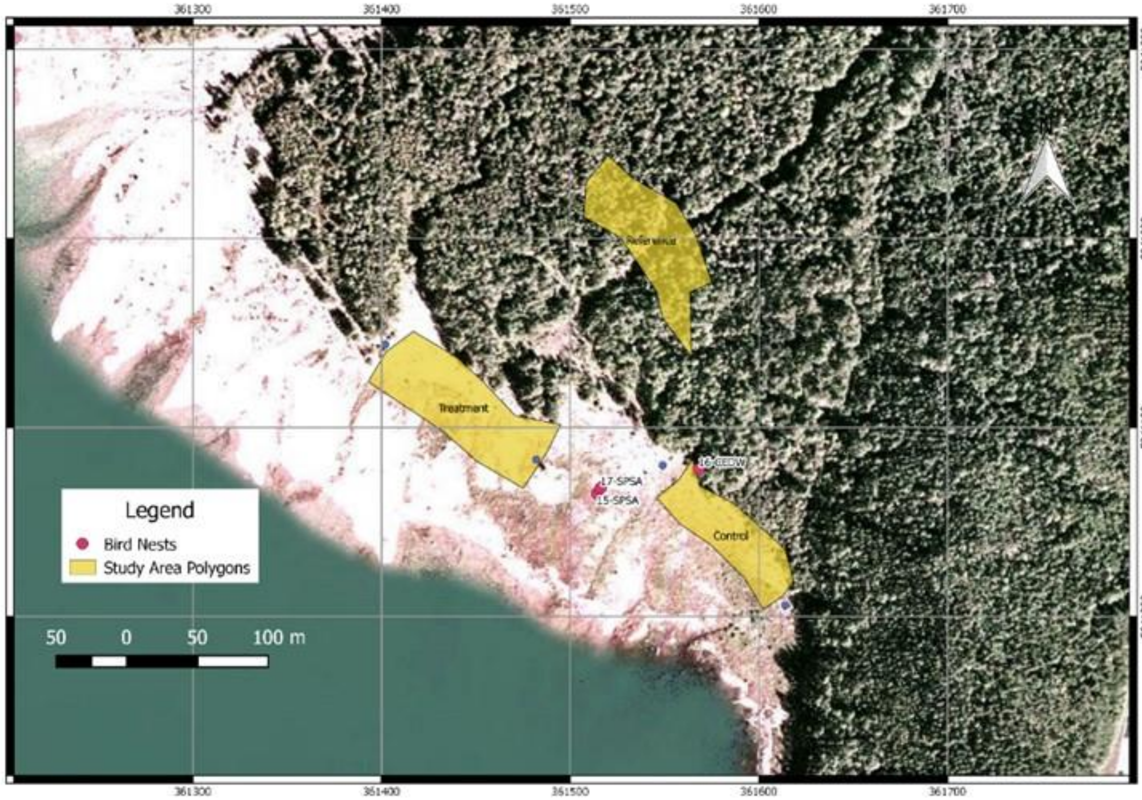

Figure 6-19: Locations of treatment, control and forest reference polygons and detected bird nests at Yellowjacket Creek in Canoe Reach, Kinbasket reservoir.

6.2.2 Terrestrial Arthropods

At Yellowjacket Creek (YJ), pitfall trap samples caught a variable number of spiders and beetles per trap-day over the four years of monitoring, even for the control plots (Figure 6-20). In particular, the relative abundance of beetles increased in 2016 and 2017, relative to earlier years, for both treatment and control plots. Rather than depicting a direct response to the treatment itself, the increase in beetle catch is more likely related to the inter-annual changes in climate, vegetation, and/or substrate characteristics, since the control plots also exhibited a similar increase in relative abundance. Relative abundance of spiders has remained low and fairly consistent at the YJ treatment area. Despite re-treatment in 2017 that resulted in soil disturbance, relative abundance of spiders and beetles in the treatment area remained comparable to 2016.

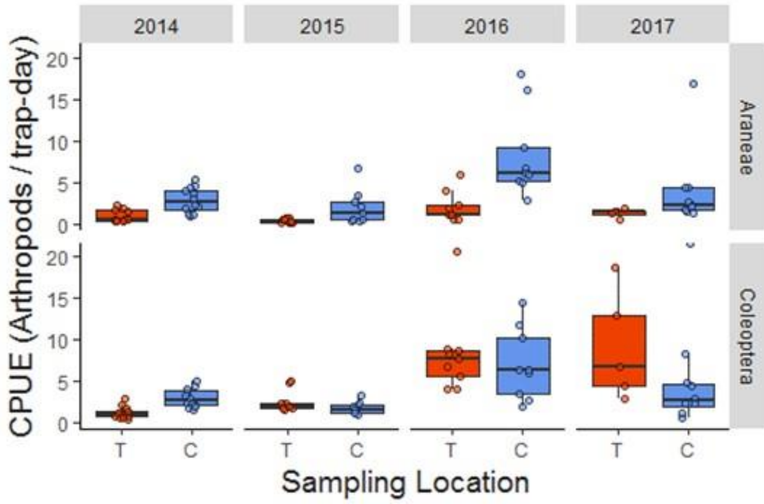

Figure 6-20: Spider and beetle catch per unit effort (CPUE) for pitfall traps by year and treatment type at Yellowjacket Creek. Points for each array (collections pooled) are overlaid on boxplots, jittered to avoid overlap.

Over the four years of sampling at Yellowjacket Creek, we have identified 70 species of arthropods from the treatment area and 116 species from control area. Patterns in richness varied greatly among sampling areas by year, with treatment richness values similar to control richness (Figure 6-21; overlapping 95% confidence intervals). Consistent with results of previous years, richness does not appear to be an informative metric for monitoring post-treatment arthropod responses.

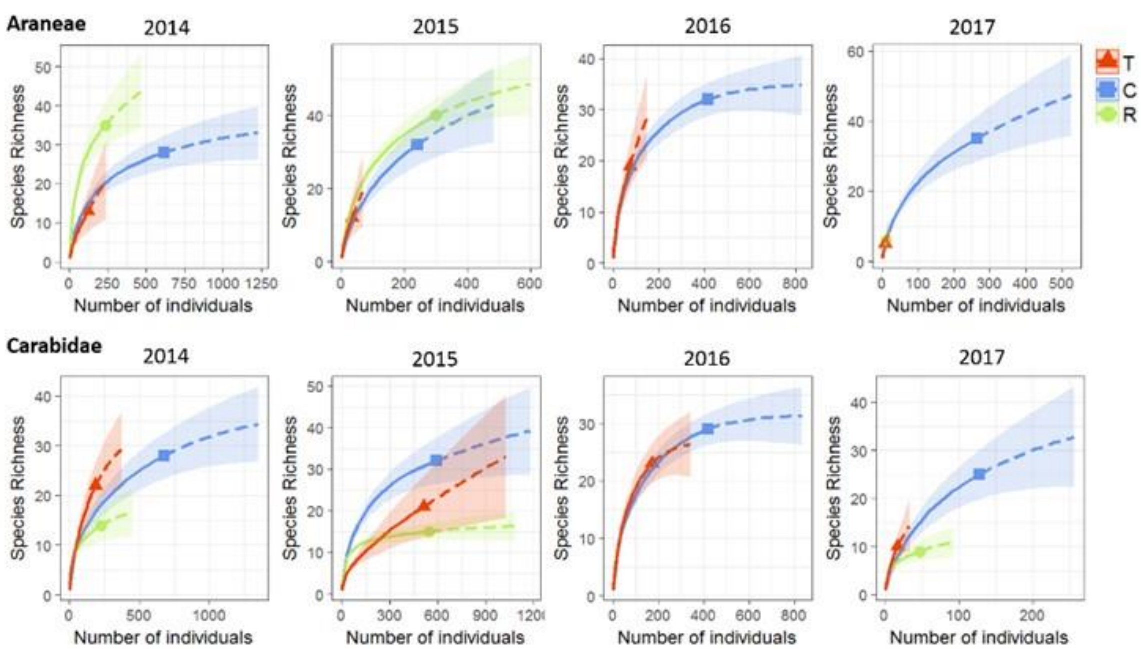

Figure 6-21: Spider and Ground beetle species richness by habitat type and year at Yellowjacket Creek. Richness is standardized per individual collected. Shaded regions indicate the 95% confidence interval around each richness curve. Points are given at the observed species richness value for each habitat type, followed by extrapolated species richness (dashed line). Solid line = interpolated species richness. Habitat types: T= treatment, C= control, R= upland reference.

Arthropod assemblages were significantly different between the treatment and control area at Yellowjacket Creek (Table 6-4). Spider composition was more dissimilar between treatment and control samples than beetle composition (Figure 6-22), albeit both were relatively dissimilar.

Table 6-4: Results of PERMANOVA test for differences in arthropod assemblages by treatment type (Treatment vs Control), blocked by year. Analysis was run with 9999 permutations and Bray-Curtis Dissimilarity

	Df	SS	MS	F	R^2	p-value
T vs C	1	4.4187	4.4187	18.879	0.20774	0.0001 ***
Residuals	72	16.8517	0.2341		0.79226	
Total	73	21.2704			1	

The control samples had more unique species than treatment samples in every year for both spiders and ground beetles. While the treatment generally had fewer than half of its total species shared with controls, in 2017 we collected few spiders at this site, and 4 out of 5 of these species occurred in the control.

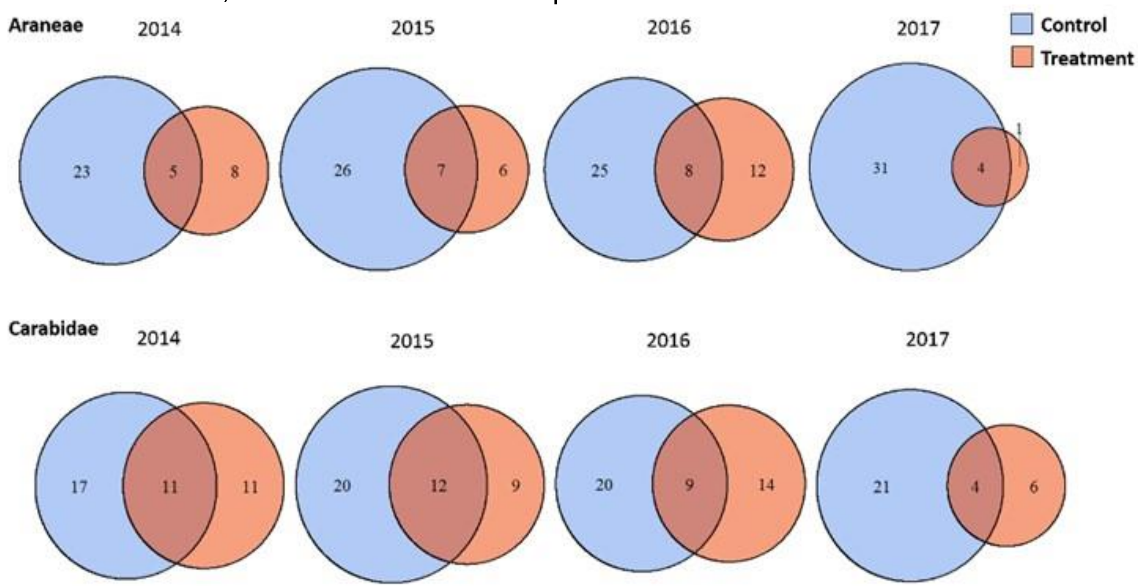

Figure 6-22: Venn diagrams of species composition for target arthropod taxa by year and habitat type at Yellowjacket Creek. Number of species unique to each habitat type is given for control and treatment plots, with the number of shared species provided in the overlapping regions. Extent of overlap is proportional to the assemblage similarity between habitats.

Species-specific response trends are becoming more salient with multiple years of monitoring data since wood removal. Clearly, some beetle and spider species are increasing with years since wood removal, such as *Pterostichus adstrictus, Cicindela oregona, Bembidion quadrimaculatum* (Coleoptera: Carabidae) and *Scotinella pugnata*, and *Alopecosa aculeata*. One ground beetle species that was very abundant in early years of monitoring, *Bembidion planatum*, has been steadily decreasing in relative abundance with years since wood removal- and was not collected from this site in 2017. One spider species, *Zelotes fratis*, has exhibited a similar pattern in decline since wood removal. Many other species show variable patterns which likely relate to differences in habitat preferences and niche breadth for each species. Nonetheless, responses are evident at the species level, which reflect small-scale spatial and temporal ecological change. Additional data from the final year of monitoring in 2018 will reveal if these trends hold over time.

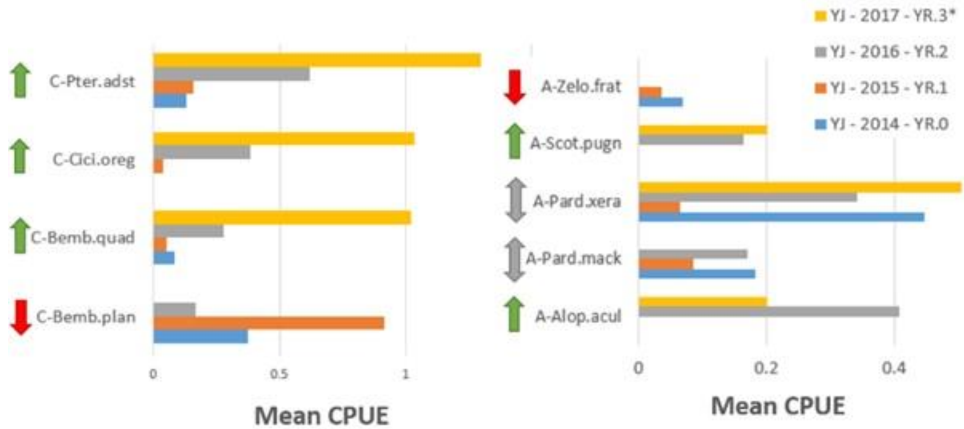

Figure 6-23: Relative abundance (adult catch per trap-day) of select ground beetles (left) and spiders (right) in the treatment area by years since wood removal application at Yellowjacket Creek. Arrows are provided for ease of interpretation, where abundance increase since wood removal is shown in a green, upward facing arrow, declining abundance since treatment is shown by a red, downward facing arrow, and uncertain trends are given by grey arrows. A- Araneae, C- Coleoptera

6.3 Bush Arm Causeway NW – Bush Arm

Site information for Bush Arm Causeway NW is presented in Table 6-5, Figure 6-24 and Figure 6-25.

Table 6-5 Site description and revegetation prescription information for Bush Arm Causeway NW, Kinbasket reservoir (BAC-N; Table 3-2).

<table>
<tr><th>Site Description:</th><th colspan="2">Site information:</th></tr>
<tr><td rowspan="4">Bush Arm Causeway NW is within Bush Arm Reach, located at the south-eastern end of Kinbasket Reservoir. This site is located within the Bush River floodplain and therefore has wet soil conditions compared to other sites due to regular water inputs from both ground and surface. The substrate composition is primarily mineral soils with a standing water component. The mineral soil is very fine-textured and possess a high clay content.</td><td>Reach</td><td>Bush Arm</td></tr>
<tr><td>UTM</td><td>11U 474580E, 5739911N</td></tr>
<tr><td>BEC Zone</td><td>ICH mw1</td></tr>
<tr><td>Elevation (m)</td><td>Min: 750 Max: 754</td></tr>
<tr><th colspan="3">Treatment Prescription</th></tr>
<tr><td colspan="3">Woody debris removal (including three wood-choked ponds), mounding, and log-boom installation occurred in the fall of 2015 after field surveys were completed. Approximately 43 salvaged sedge plants were transplanted onto the margins of one of the cleared ponds (Hawkes 2017).</td></tr>
<tr><th colspan="3">Summary of Prescription</th></tr>
<tr><td colspan="3">Compared to other sites at pre-treatment, Bush Arm Causeway NW yielded the highest number of vascular plant species (richness). Forbs made up the highest proportion of species, followed either by shrubs and sedge-like plants, and cover values were relatively consistent between treatment and control polygons. Preliminary assessments of revegetation prescriptions indicate that vegetation are growing on the mounds and in areas cleared of wood debris, and that all transplanted sedge plugs are established and growing (100% survival). Assessments for revegetation following the removal of woody debris within the log boom have not been conducted. Mound erosion and integrity following inundation was not tested because reservoir levels did not reach inundation levels (full pool) in 2016. In 2016 aquatic macrophytes returned to wetlands cleared of woody debris (Hawkes 2017).</td></tr>
</table>

Figure 6-24: The Bush Causeway North site showing physical works treatment mounds (yellow polygons), cleared ponds (blue polygons), and log boom installation (red line). Photo: Hawkes 2017.

Figure 6-25: The Bush Causeway North treatment site showing mounds, cleared ponds, establishing vegetation on mounds (bottom left), and live stakes (bottom right). Photos were taken June 18, 2017.

Substrate composition at Bush Arm Causeway NW has changed over time, particularly when comparing live organic matter cover in pre-treatment (2015) year vs post-treatment years (Figure 6-26). Despite the encouraging pattern, the control also measured a similar increase in vegetation over these years. These plots did not overlap with the vegetation transplants and is merely reflective of the surrounding vegetation where songbird surveys and arthropod sampling are conducted. The only valid pattern in substrate composition is the reduction in wood debris in the treatment polygon over time. The average cover of bare soil also decreased for the BAC-N treatment since 2016.

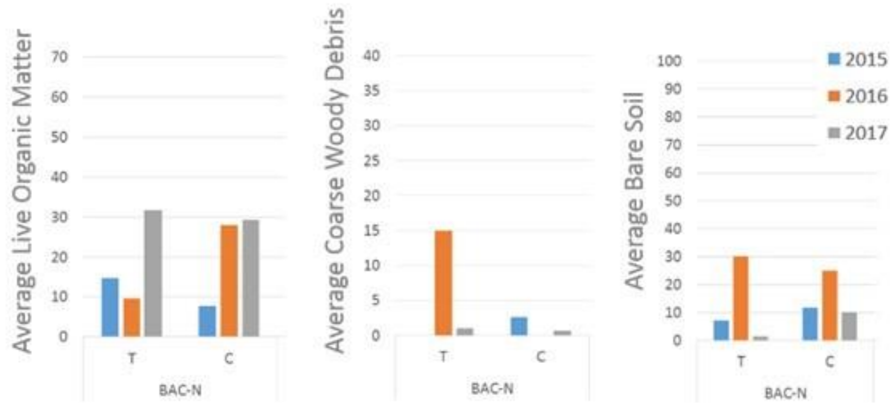

Figure 6-26: Mean per cent cover of vegetation (LOM), coarse wood, and bare soil recorded at treatment (T) and control (C) pitfall trapping stations.

6.3.1 Birds

Reference

A total of 41 species were detected during point counts in Reference areas at Bush Arm Causeway NW from 2015-2017. Three point-count stations were established along a forestry spur road immediately to the north of the reservoir. These points mostly sampled coniferous forest and forest edge habitat roughly 85-180 m from the shoreline edge of the reservoir on the north side of the causeway. Swainson's Thrush (43 observations), Hammond's Flycatcher (26 observations), Yellow-rumped Warbler (17 observations), and Ruby-crowned Kinglet (16 observations), were the most commonly detected species at all distance bands. One observation of two Barn Swallows (provincially blue-listed, federally listed as Threatened under Schedule 1 of the Species at Risk Act) seen on 07 July 2017 was the only species of conservation concern detected.

When only constrained data are considered, a total of 49 observations of 20 species remain. Fourteen of these 20 species were detected in only one of the three survey years, with only three species (Swainson's Thrush, Hammond's Flycatcher, and Golden-crowned Kinglet) detected in all three survey years. Hammond's Flycatcher (9 observations), Swainson's Thrush (8 observations), Golden-crowned Kinglet (5 observations), and Yellow-rumped Warbler (5 observations) were the most frequently detected species over all years. Though less pronounced than at Canoe Reach sites, inter-annual variation in species richness and diversity was noted from 2015-2017 (Figure 6-27). In particular, both metrics were highest in 2016, despite equal sampling effort in 2017 and no obvious change in vegetation community. The 2015 and 2016 years appeared to be more similar to each other than either year was to 2017, when a relative reduction in both richness and diversity was noted.

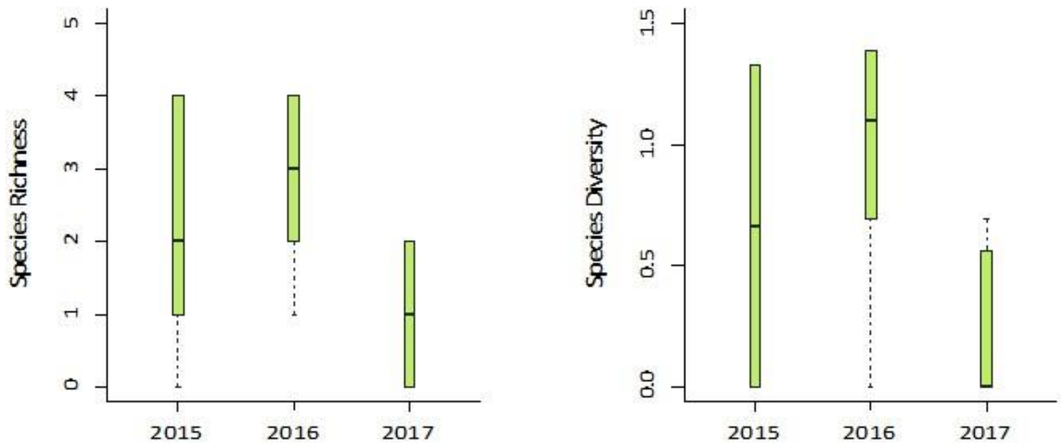

Figure 6-27: Boxplots showing bird species richness (left) and Shannon's diversity index (right) for reference point counts at Bush Arm Causeway NW from 2015-2017. Note that differences, while appearing large in the graphs, are relatively minor (i.e., median richness differs by ~1-2 species).

Treatment and Control

Woody debris removal, mounding, and log-boom installation occurred during 2015, after bird surveys had completed for the year. Thus, 2015 data is the pre-treatment phase, while 2016 represents the first year of post-treatment monitoring. During the initial pre-treatment year, control and treatment transects had similar richness and diversity values (Figure 6-28). In the year immediately post-treatment, both richness and diversity were significantly greater in the treatment compared to the control transect. By year-two post-treatment, that disparity declined, and median richness and diversity were equal for control and treatment transects, with richness values similar to pre-treatment levels. During all three years (pre- and post-treatment periods) both richness and diversity remained consistent at control transects, suggesting that differences noted in treatments may actually relate to treatment effects. However, as the results from the reference plot mirror this same trend to some degree, we cannot attribute the trends observed for treatment transects as definitive evidence of revegetation prescription success regarding bird use.

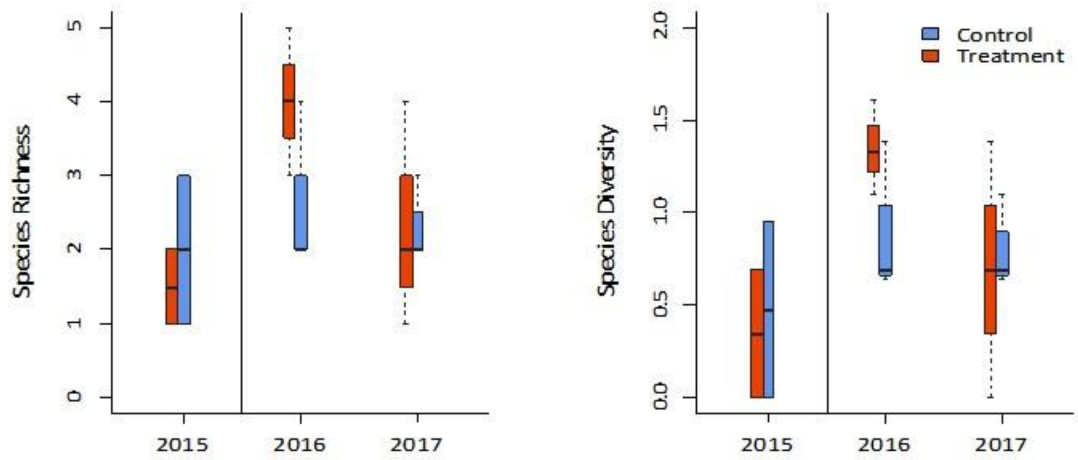

Figure 6-28: Boxplots showing bird species richness (left) and Shannon's diversity index (right) for control (blue boxes) and treatment (red boxes) transects at Bush Arm Causeway NW over three years of surveying. Initial woody debris removal, mounding, and log-boom installation occurred in 2015 after bird surveys had finished (black vertical line).

A total of 26 species have been detected at all distances from both treatment and control transects at Bush Arm Causeway NW. When data is constrained, the result is 46 observations of 16 species over three years of surveys. One of these species, the Barn Swallow, is listed as a species of conservation concern (provincially blue-listed and federally listed as Threatened). Most of the species have been detected from the treatment transect, which also had the highest number of unique species (Figure 6-29). Many of the unique species in the treatment transect, such as Willow Flycatcher and Warbling Vireo, are reflective of proximity to shrubby and treed habitats at its northern end. Many of the shared species are open-country species that are widespread throughout the Kinbasket Reservoir drawdown zone and have potential to be indicators of revegetation or woody debris removal effectiveness. These include Savannah Sparrow, Spotted Sandpiper, and Killdeer. Savannah Sparrow was the most commonly detected species in these transects (5 observations on each transect). Spotted Sandpiper had four detections from the control transect and one from the treatment. Killdeer was only detected twice, once from each transect, detected within both the treatment and control transects. Ten species were detected only in one year, with the other six all found on two different years.

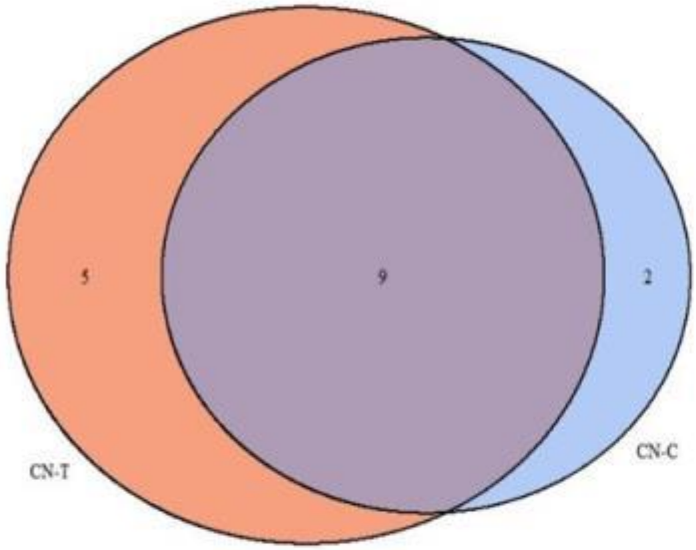

Figure 6-29: Venn diagram showing the number of bird species in the constrained dataset observed at Bush Arm Causeway NW that were unique to control transects (blue area), treatment transects (red area), and shared between the transects (overlapping mauve area). Circles are proportional to the number of observed species.

Nesting Birds

A number of nests have been located from the Bush Arm Causeway NW area. These include eight Savannah Sparrow nests and seven Spotted Sandpiper nests (Figure 6-30). Both species are noted as potential indicators of revegetation success, with Spotted Sandpipers potentially occurring in more open, gravelly substrates, and Savannah sparrows preferring areas of denser grasses and sedges with some shrubs. Seven nests have been documented in the control polygon, with equal numbers of Savannah Sparrow and Spotted Sandpiper nests. Only three nests have been documented from the treatment polygon, including one each of Savannah Sparrow, Spotted Sandpiper, and Lincoln's Sparrow. The Savannah Sparrow and Spotted Sandpiper nests were both located in 2017. It is possible that woody debris removal and exclusion may increase the suitability of the treatment area for nesting birds over time. All the located nests at this site are from open-country species that do not require much vertical vegetation growth for suitable nesting habitat.

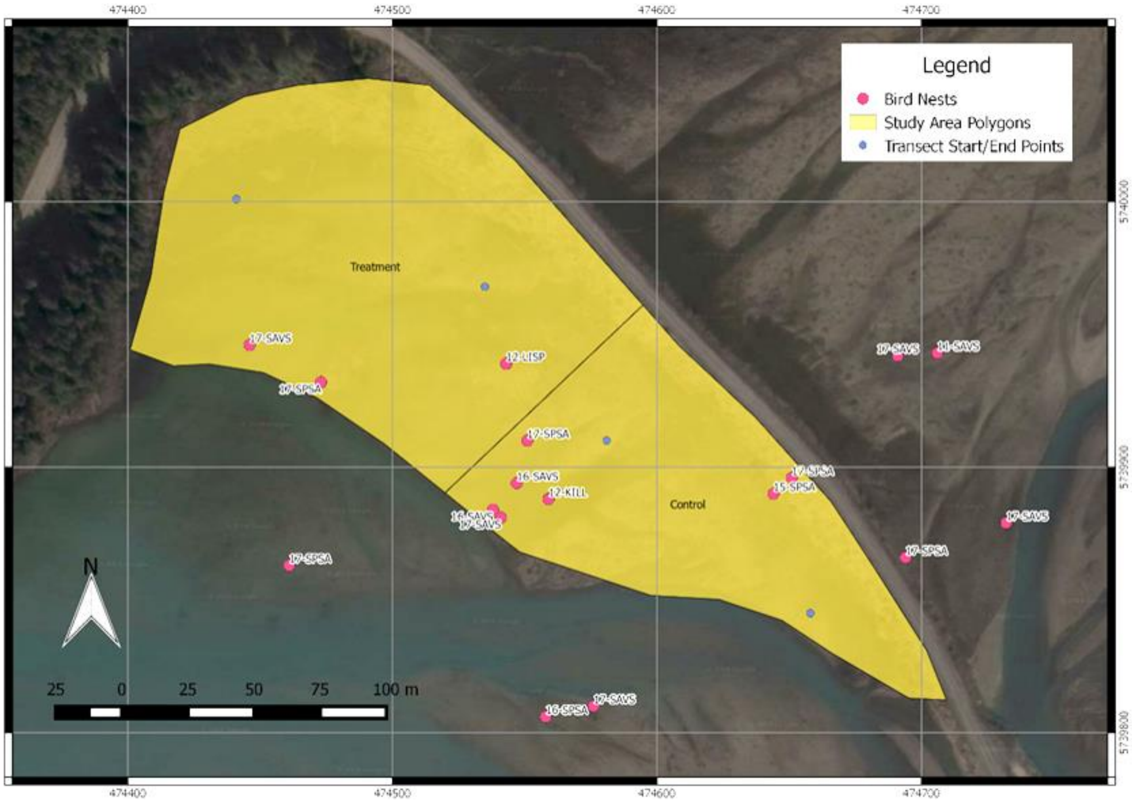

Figure 6-30: Locations of treatment, control and forest reference polygons and detected bird nests at Bush Arm Causeway NW at Bush Arm, Kinbasket reservoir.

6.3.2 Terrestrial Arthropods

Relative abundance (Catch per unit effort, CPUE) of spiders and beetles was variable at Bush Arm Causeway Northwest (BAC-N) over the past years of monitoring (Figure 6-9). Compared to pre-treatment data (2015), the post treatment relative abundance of spiders has increased in both treatment and control sampling areas. At this site, beetle catch was greater at treatment than control plots in pre-treatment sampling (2015) as well as 2017 sampling. Thus, the greater beetle catch in the 2017 samples from treatment areas should not be attributed to an effect of the physical works prescriptions applied at this site. An increase in arthropod abundance within all treatment and control sites in recent years could be due to increased habitat availability related to lower reservoir maxima since 2013 (Figure 3-1).

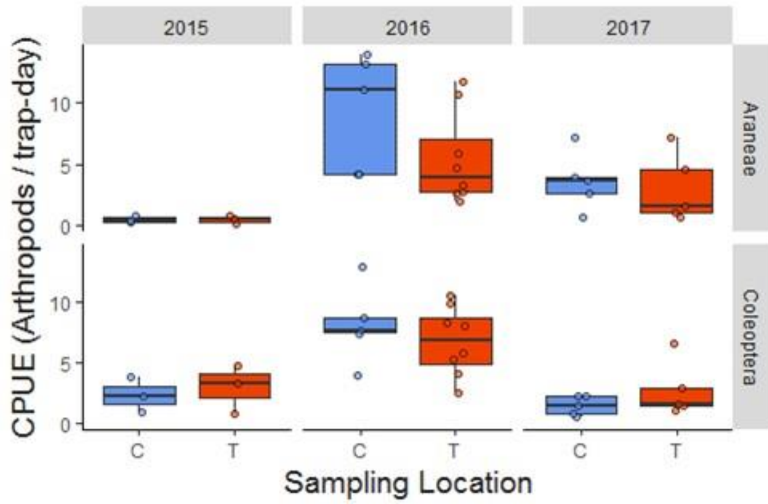

Figure 6-31: Spider and beetle catch per unit effort (CPUE) for pitfall traps by year and treatment type at Bush Arm Causeway NW. Points for each array (collections pooled) are overlaid on boxplots, jittered to avoid overlap. Note: 2015 was pre-treatment

Patterns in richness suggest that there is a possible divergence in richness between treatment and control plots over time at BAC-N (Figure 6-32). For spiders, richness tended to be greater at the treatment (not significantly) than the control in 2015 and 2016, while the reverse pattern was observed in 2017 (control tended to have greater richness than treatment). For beetles, standardized richness was nearly equal between treatment and control in 2015 and 2016, but 2017 data suggests a possible divergence between study plots.

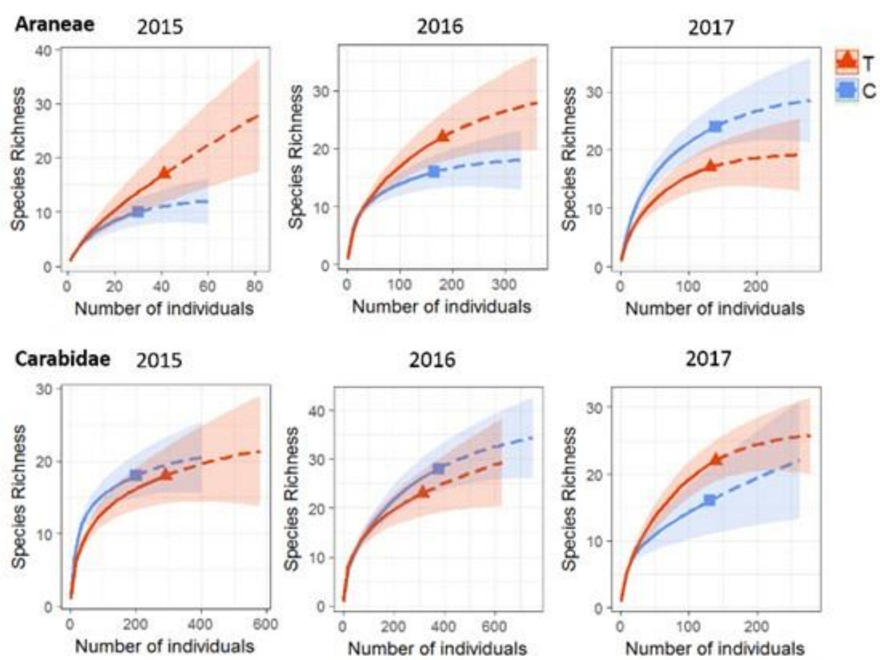

Figure 6-32: Spider and Ground beetle species richness by habitat type and year at Bush Arm Causeway NW. Richness is standardized per individual collected. Shaded regions indicate the 95% confidence interval around each richness curve. Points are given at the observed species richness value for each habitat type, followed by

extrapolated species richness (dashed line). Solid line = interpolated species richness. Habitat types: T= treatment, C= control, R= upland reference

Interestingly, not only are the number of spider species collected (corrected for sampling effort) diverging between treatment and control plots, the identities of these species differ in 2017, such that control samples had three-fold the number of unique species not found in the adjacent treatment area (Figure 6-33). The proportion of shared beetle species (Carabidae) has declined since pre-treatment sampling in 2015, when ground beetle composition was nearly identical between treatment and control plots. Although control samples have a large portion of species still in common with treatments in 2017, the treatment area yielded more unique species than in pre-treatment sampling. Despite these trends, arthropod assemblages were not found to be significantly different between the treatment and control samples at this site (Table 6-6). Examination of Year-by-Treatment contrasts, suggests that although treatment assemblages were marginally different than control assemblages in 2016 (F= 1.968, df= 12, p= 0.077), this did not hold for 2017 (F= 0.868, df= 9, p= 0.514). In addition, treatment assemblages were not found to significantly differ between pre-treatment sampling in 2015 and post-treatment sampling in 2017 (F=1.562, df= 7, p= 0.19), despite that assemblages changed in the first year post-treatment (2016) compared to 2015 (F=2.791, df= 10, p= 0.01).

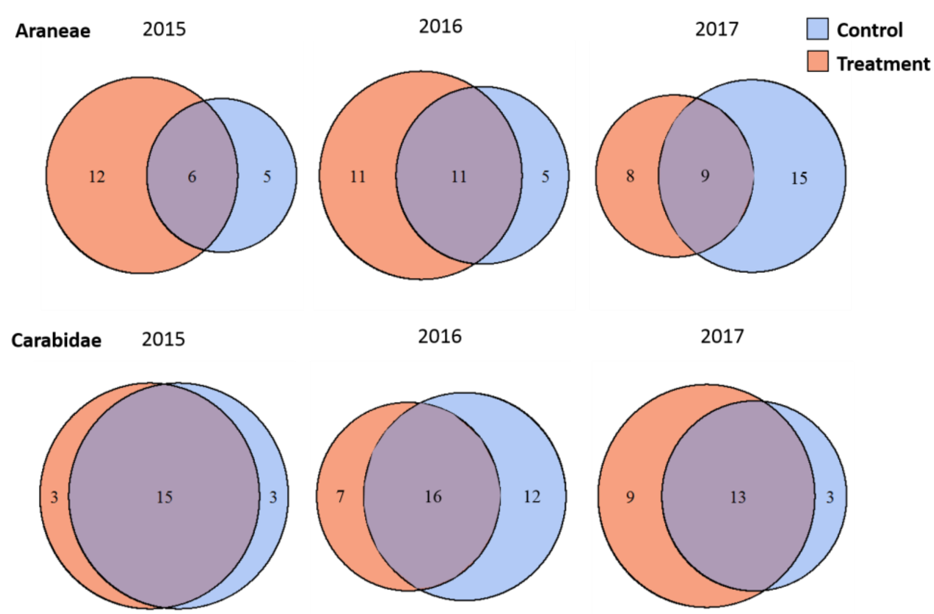

Figure 6-33: Venn diagrams of species composition for target arthropod taxa by year and habitat type at Bush Arm Causeway NW. Number of species unique to each habitat type is given for control and treatment plots, with the number of shared species provided in the overlapping regions. Extent of overlap is proportional to the assemblage similarity between habitats.

Table 6-6: Results of PERMANOVA test for differences in arthropod assemblages by treatment type (Treatment vs Control), blocked by year. Analysis was run with 9999 permutations and Bray-Curtis Dissimilarity

	Df	SS	MS	F	R^2	p-value
T vs C	1	0.2846	0.28457	1.0335	0.03687	0.2118
Residuals	27	7.4342	0.27534		0.96313	
Total	28	7.7188			1	

6.4 Bush Arm Causeway SW – Bush Arm

Site information for Bush Arm Causeway SW is presented in Table 6-7 and Figure 6-34, Figure 6-35, and Figure 6-37.

Table 6-7 Site description and revegetation prescription information for Bush Arm Causeway SW at Bush Arm, Kinbasket reservoir (BAC-S; Table 3-2).

<table>
<tr><th>Site Description:</th><th colspan="2">Site information:</th></tr>
<tr><td rowspan="4">Bush Arm Causeway SW is within Bush Arm Reach, located at the south-eastern end of Kinbasket Reservoir. The substrate consists of mineral soils that are a fairly balanced mix of silt, sand, organics, and fines. There is also a relatively high proportional cover of wood debris and decaying organic matter.</td><td>Reach</td><td>Bush Arm</td></tr>
<tr><td>UTM</td><td>11U 474680E, 5739048N</td></tr>
<tr><td>BEC Zone</td><td>ICH mw1</td></tr>
<tr><td>Elevation (m)</td><td>Min: 750 Max: 754</td></tr>
<tr><th colspan="3">Treatment Prescription</th></tr>
<tr><td colspan="3">Woody debris removal and mounding occurred in the fall of 2015 after field surveys were completed. Approximately 106 live deciduous stakes (mainly black cottonwood) were planted in and around the mound in 2015 and 2016 (Hawkes 2017).</td></tr>
<tr><th colspan="3">Summary of Prescription</th></tr>
<tr><td colspan="3">Compared to other sites at pre-treatment, Bush Arm Causeway SW was moderately speciose (rich). Cover values for the herb layer were relatively consistent between treatment and control polygons. However, for shrubs, control transects exhibited higher average species richness and cover values than the matching treatment transects at pre-treatment. Preliminary assessments indicate that vegetation (Rose, black cottonwood, sedges, horsetail, grasses) are growing on the mounds and in areas cleared of wood debris. (Hawkes 2017). Live stake survival varied between mounds, with stakes planted in the fall surviving better than those planted in the spring (93.5% vs. 20%), with an overall survival of 71% (Hawkes 2017). Mound erosion and integrity following inundation was not tested because reservoir levels did not reach inundation levels in 2016 or 2017.</td></tr>
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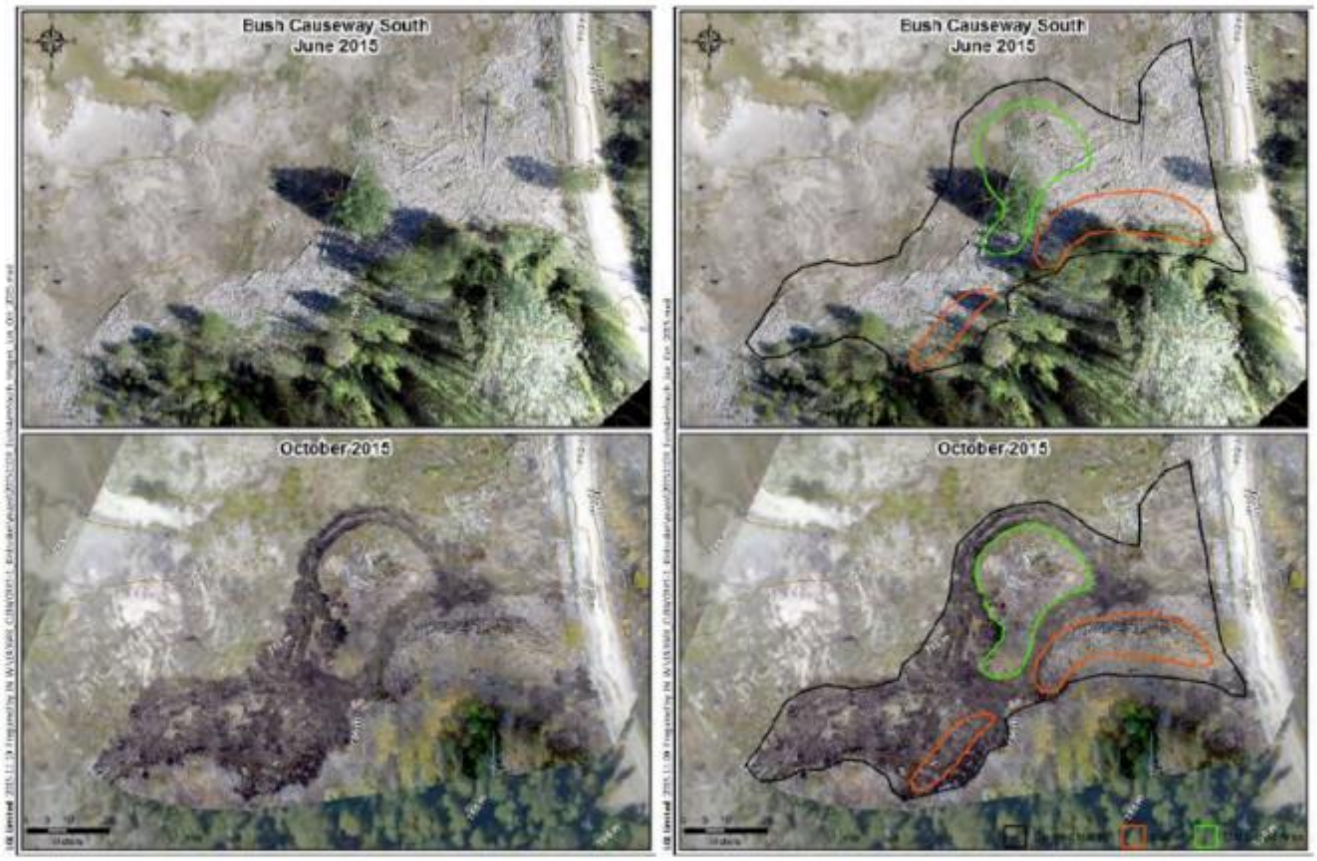

Figure 6-34: The Bush Causeway South site prior to construction (top left) and following clearing and construction of the mounds (bottom left). Polygons delineate the area cleared (black polygon), not cleared (green polygon), and the two mounds (top right, bottom right; red polygons). Images obtained via drone (operated by Murray Chapple, Sterling Lumber)

Figure 6-35: Overview photos of the treatment (top) and control (bottom) sampling areas at Bush Arm Causeway SW in 2016 (left) and 2017 (right). Note the wood debris mounds in the treatment area and dispersed wood accumulation in the control. Photos were taken June 16, 2016 and June 18, 2017

Substrate composition at Bush Arm Causeway SW has remained fairly stable over the pre-treatment (2015) and post-treatment (2016-2017) years (Figure 6-15). The most noticeable differences are the treatment plot decrease in wood debris (since wood removal) and decrease in bare soil (which was also evident for the control area), indicating increased ground cover.

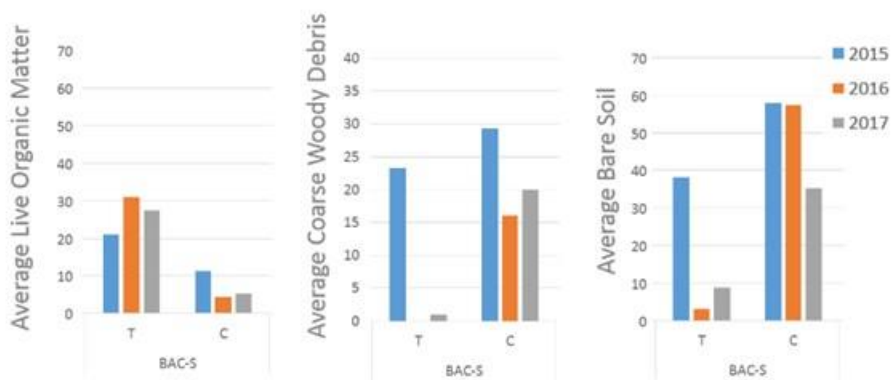

Figure 6-36: Mean per cent cover of vegetation (LOM), coarse wood, and bare soil recorded at treatment (T) and control (C) pitfall trapping stations.

Figure 6-37: Examples of natural vegetation establishment in mounds and cleared areas at Bush Arm Causeway. Top: *Rosa* sp., *Populus trichocarpa ssp. balsamifera* seedlings, and *Salix* sp. on mounds; middle: *Equisetum* sp. on cleared areas at BAC-N; and bottom: *Equisetum* sp. and *Calamagrostis* sp. on cleared areas of BAC-S. Natural vegetation establishment occurred within the first growing season following clearing in October 2015 [Photos from Hawkes 2017]

6.4.1 Birds

Reference

A total of 37 species were detected during point counts in reference areas at Bush Arm Causeway SW from 2015-2017. Three point-count stations were established in mixedwood, interior forest to the south and west of the drawdown zone line transects, and roughly 60 m from the closest shoreline edge of the reservoir. Warbling Vireo (29 observations), Swainson's Thrush (25 observations), and American Redstart (23 observations) were the most commonly detected species at all distance bands. One observation of a Bank Swallow (federally listed as Threatened under Schedule 1 of the Species at Risk Act) seen on 09 July 2015 was the only species of conservation concern detected.

When only constrained data are considered, a total of 48 observations of 18 species remain. Twelve of these 18 species were detected in only one of the three survey years, with only the two most common species (American Redstart – 11 observations and Warbling Vireo – 8 observations) detected in all three survey years. From 2015-2017, as with other sites, inter-annual variation in species richness and diversity was noted (Figure 6-38). In particular, both metrics were highest in 2016 and lowest in 2017, a trend observed from all other sites at both Canoe Reach and Bush Arm, though least pronounced at Bush Arm Causeway SW. Sampling effort was equal in 2016 and 2017, and no obvious change in vegetation community occurred among years.

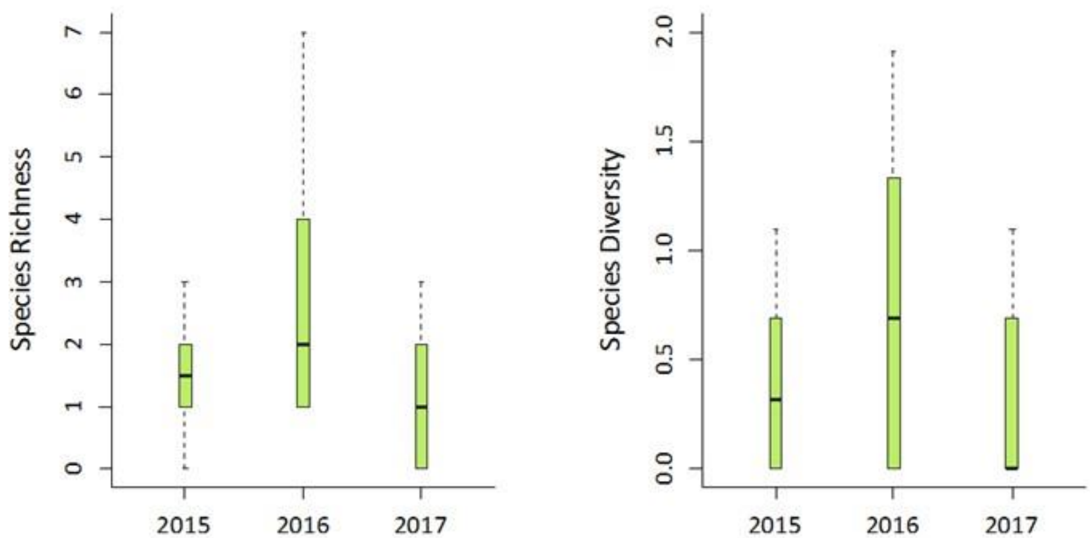

Figure 6-38: Boxplots showing bird species richness (left) and Shannon's diversity index (right) for reference point counts at Bush Arm Causeway SW from 2015-2017. Note that differences, while appearing large in the graphs, are relatively minor (i.e., median richness differs by ~1 species).

Treatment and Control

Woody debris removal and mounding occurred during 2015, after bird surveys had completed for the year. Thus, 2015 data is the pre-treatment phase, while 2016 represents the first year of post-treatment monitoring (Figure 6-39). During the single pre-treatment year, there were very few birds encountered in the control transect, for unknown reasons. Following the revegetation physical works, richness, and diversity of both treatment and control transects increased. Richness and diversity were equivalent at both treatment and control transects in 2016. In 2017, while both richness and diversity declined at both transects, the decline was disproportionate at the treatment transect. It is not known to what extent, if any, this disproportionate decline at the treatment transect was related to revegetation prescriptions, however, reductions in bird numbers in 2017 were noted throughout our study areas (both within drawdown zone and reference areas).

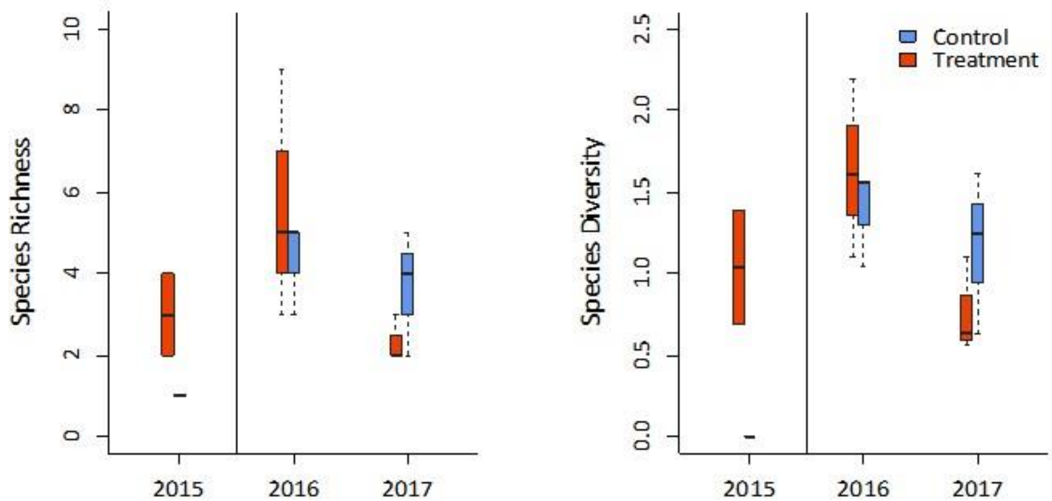

Figure 6-39: Boxplots showing bird species richness (left) and Shannon's diversity index (right) for control (blue boxes) and treatment (red boxes) transects at Bush Arm Causeway SW over three years of surveying. Initial woody debris removal, mounding, and log-boom installation occurred in 2015 after bird surveys had finished (black vertical line).

A total of 32 species have been detected at all distances from both treatment and control transects at Bush Arm Causeway SW. When data is constrained, the result is 65 observations of 20 species over three years of surveys. Two of these species are listed as species of conservation concern: Barn Swallow (provincially blue-listed and federally listed as Threatened), and Evening Grosbeak (listed as Special Concern by COSEWIC). Most of the species have been detected from the treatment transect, which also had the highest number of unique species (Figure 6-40). Many of the unique species in the treatment transect, such as Song Sparrow, Mountain Bluebird, Killdeer, and Common Yellowthroat are open-country and/or shrub-preferring species that may benefit from these physical works. Lincoln's Sparrow was the most commonly detected species in these transects, with roughly equal number of observations in each transect (8 and 9 in control and treatment respectively). Savannah Sparrow had the second higher number of observations (10), with all but one occurring in the treatment transect. (5 observations on each transect). Eleven species were detected only in one year, with only Chipping and Savannah Sparrows being detected in all three survey years.

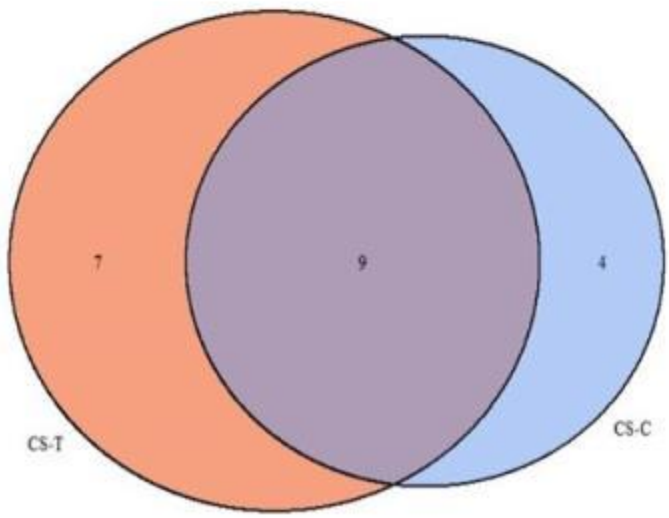

Figure 6-40: Venn diagram showing the number of bird species in the constrained dataset observed at Bush Arm Causeway SW that were unique to control transects (blue area), treatment transects (red area), and shared between the transects (overlapping mauve area). Circles are proportional to the number of observed species.

Nesting Birds

The drawdown zone is more limited at Bush Arm Causeway SW compared to Bush Arm Causeway NW and Valemount Peatland North, potentially limiting nesting opportunities for open-country species at this site. Few nests have been discovered in the treatment polygon, the exception being a Northern Flicker nesting within an old stump (Figure 6-41). Both Killdeer and Spotted Sandpiper nests have been found in proximity to the polygon, and future nesting may be documented where physical prescriptions have been applied. The control polygon at this site is characterized by large amounts of woody debris, but also greater shrub cover. The woody debris may limit nesting by open-country species. The only nest within the polygon, and multiple nests in proximity, belonged to Chipping Sparrows. Multiple Cedar Waxwing nests immediately west of the polygon also refer to greater tree and shrub cover near this polygon. It is noteworthy that a Savannah Sparrow nest was found close to the control polygon in a grassy area. This indicates, along with the multiple Savannah Sparrow nesting occurrences at Bush Arm Causeway NW, that Savannah Sparrows may breed in this area if suitable conditions (e.g., woody debris removal, revegetation success) are created/persist.

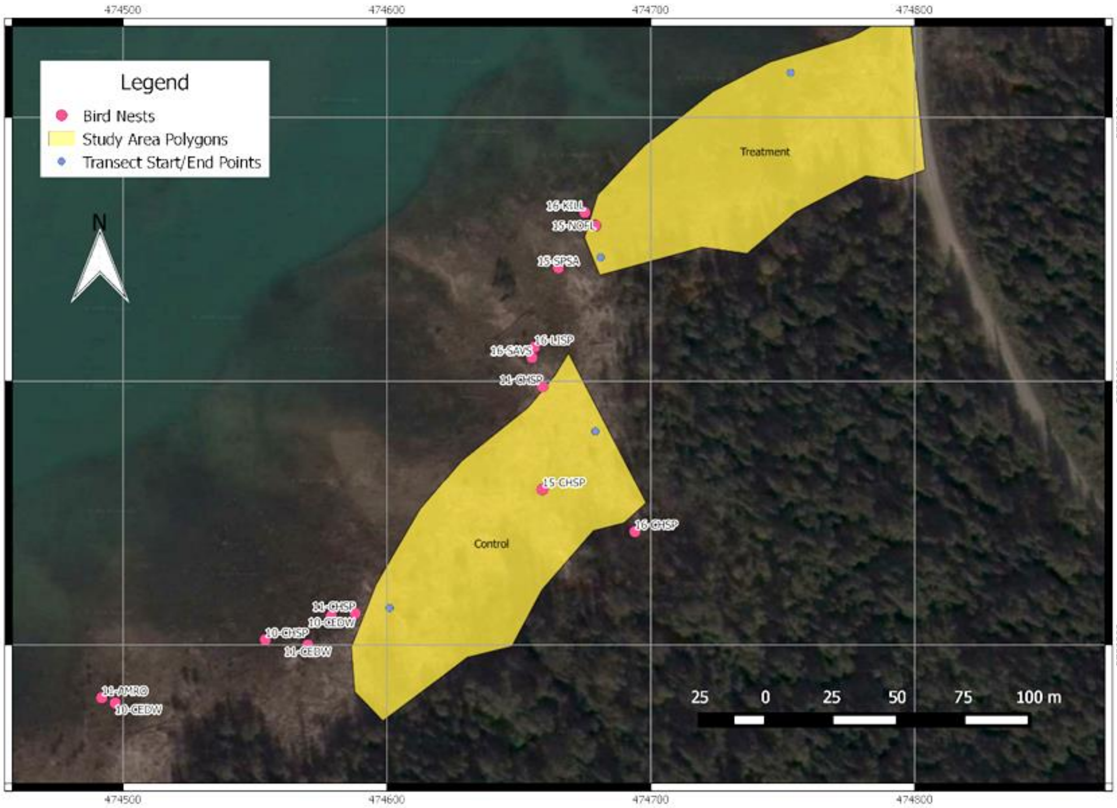

Figure 6-41 **Locations of treatment, control and forest reference polygons and detected bird nests at Bush Arm Causeway SW at Bush Arm, Kinbasket reservoir.**

6.4.2 Terrestrial Arthropods

Relative abundance (Catch per unit effort, CPUE) of spiders and beetles at Bush Arm Causeway Southwest (BAC-S) was similar between control and treatment plots for spiders but has been slightly greater in the treatment polygon for beetles for pre- and post-treatment sampling (Figure 6-42). That this pattern was observed prior to physical works implementation would encourage more comprehensive examination of the before- and after- treatment data in the comprehensive final report. For example, examining the difference in relative abundance between the plots by year may be more informative as to whether a treatment effect is possible.

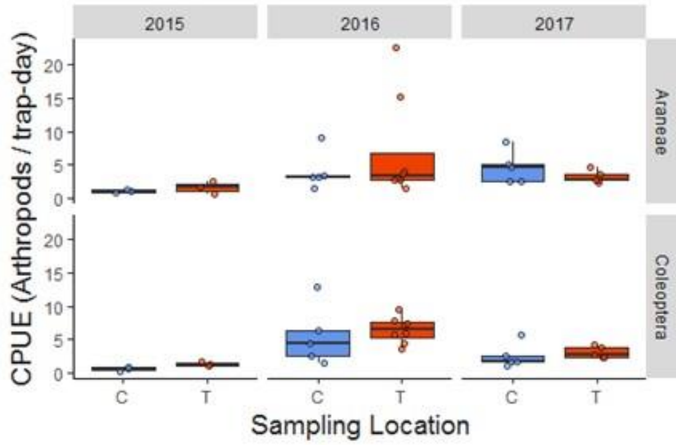

Figure 6-42: Spider and beetle catch per unit effort (CPUE) for pitfall traps by year and treatment type at Bush Arm Causeway SW. Points for each array (collections pooled) are overlaid on boxplots, jittered to avoid overlap. Note: 2015 was pre-treatment

No significant differences between treatment and control richness were found over the past three years of monitoring at BAC-S (Figure 6-43). Overall, spider richness in both treatments and controls has doubled since treatment application concurrently with increased number of individuals collected, suggesting a local change in arthropod populations not related to the treatment itself. For example, an increase in arthropod numbers and species richness in recent years could be due to the availability of the upper drawdown zone elevations throughout the past few years, as Kinbasket Reservoir has not reached full pool since September 2013 (Figure 3-1). Low reservoir elevations would make this habitat available all year round to arthropod species for foraging, reproduction, and overwintering.

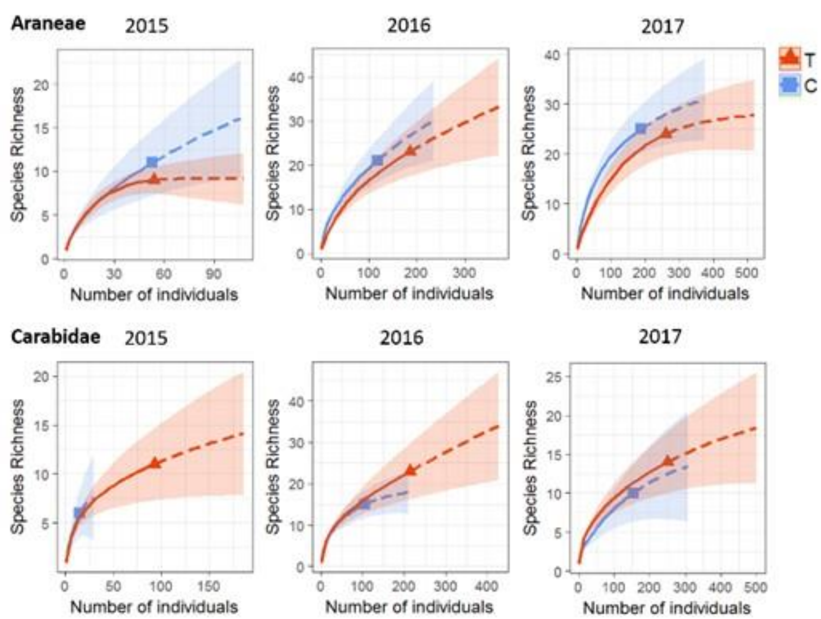

Figure 6-43: Spider and Ground beetle species richness by habitat type and year at Bush Arm Causeway SW. Richness is standardized per individual collected. Shaded regions indicate the 95% confidence interval around each richness curve. Points are given at the observed species richness value for each habitat type, followed by extrapolated species richness (dashed line). Solid line = interpolated species

richness. Habitat types: T= treatment, C= control, R= upland reference. Note: Y-axis scales differ.

Arthropod assemblages were significantly different between treatment and control samples at BAC-S (Table 6-8). Composition was most similar during pre-treatment sampling (2015), with ground beetle species especially becoming less similar in composition in post-treatment samples (Figure 6-44). Spider species composition was less similar in the initial post-treatment year (2016) than in 2015, but the proportion of shared species returned to similar pre-treatment levels in 2017.

Table 6-8: Results of PERMANOVA test for differences in arthropod assemblages by treatment type (Treatment vs Control), blocked by year. Analysis was run with 9999 permutations and Bray-Curtis Dissimilarity

	Df	SS	MS	F	R^2	p-value
T vs C	1	0.7564	0.75638	3.485	0.11432	0.0001 ***
Residuals	27	5.8601	0.21704		0.88568	
Total	28	6.6165			1	

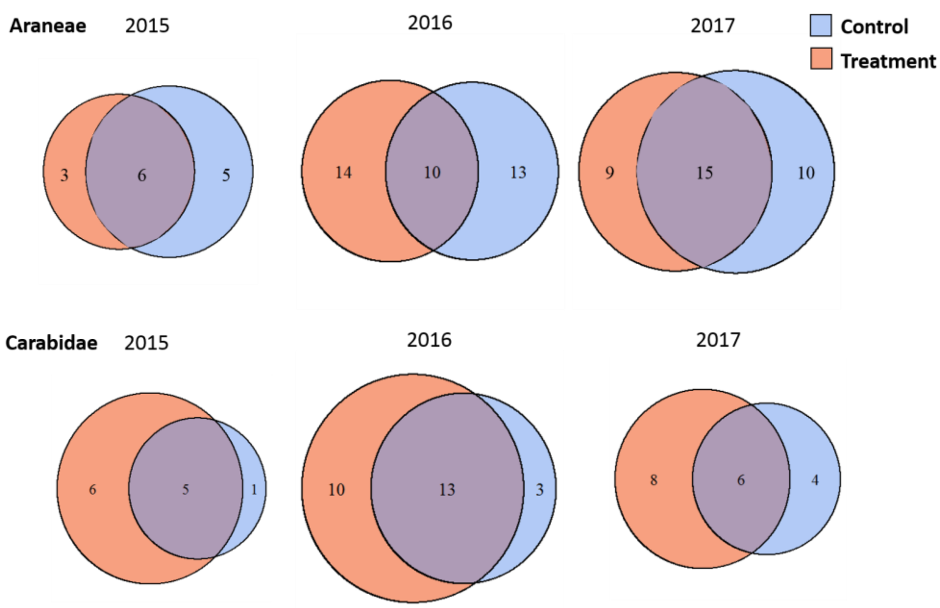

Figure 6-44: Venn diagrams of species composition for target arthropod taxa by year and habitat type at Bush Arm Causeway SW. Number of species unique to each habitat type is given for control and treatment plots, with the number of shared species provided in the overlapping regions. Extent of overlap is proportional to the assemblage similarity between habitats.

In pre-treatment sampling at this site, we collected few beetles in the genus *Amara*, however, we collected 12 and 108 individuals in 2016 and 2017 treatment samples (of four different species). *Amara* spp. are known as the "Seed-eating Ground Beetles", due to their omnivorous diet that often contains seeds of grasses, cereals, asters, and other plants (Larochelle and Larivière 2003). Thus, we expect that local populations of *Amara* are increasing in response to vegetation growth/density in this area. This pattern was even more pronounced for the control area (Figure 6-45). The vast majority of these were *Amara littoralis*, whose known predators include toads, crows, starlings, and swallows (Larochelle and Larivière 2003).

Other arthropods that have increased since treatment include *Pterostichus adstrictus* (Coleoptera: Carabidae) and *Pardosa xerampelina* (Araneae: Lycosidae), though these species show similar abundance patterns from both the treatment and control samples (Figure 6-45). One ground beetle species, *Bembidion bimaculatum*, has never been collected from the control area, but has been collected from the treatment in all years.

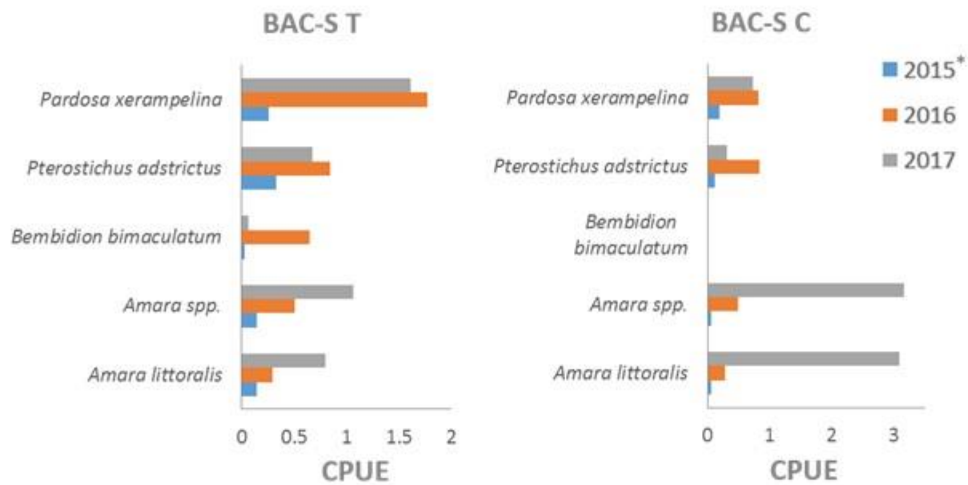

Figure 6-45: Relative abundance (adult catch per trap-day) of select ground beetles and spiders in the treatment (left) and control (right) by year. *Amara* spp. includes the abundance of all four *Amara* spp., most of which were *A. littoralis*. *Pardosa xerampelina* is the only spider featured. Note: 2015 was pre-treatment sampling

6.5 Results Summary

We conducted two years of post-treatment monitoring at the Bush Arm Causeway (BAC-S, BAC-N), three years of post-treatment monitoring at the Valemount Peatland (VP-N), and four years of post-treatment monitoring at Yellowjacket Creek (YJ). Over these years, considerable changes in vegetation cover have been documented (Figure 6-1, Figure 6-2, Figure 6-14, Figure 6-25, Figure 6-37). Within the area sampled by pitfall traps, all treatment areas were measured to have an increase in LOM, relative to initial treatment levels (Figure 6-3, Figure 6-15, Figure 6-26, Figure 6-36).

Birds and arthropod responses to revegetation and physical works trials have been quite similar. For both taxa, results were mixed for relative abundance and richness results, however, species-specific shifts have been observed for both the arthropod and bird fauna since treatment implementation at most sites.

As shown in the results, Chipping Sparrow occupied areas with shrub cover, which is starting to establish on some plots. Spotted Sandpiper and Savannah Sparrow are more characteristic of open areas with lower herbaceous vegetation and sparse ground cover. At VP-N in 2017, there was an absence of both open-country (e.g., Savannah Sparrow) species and forest-edge species (e.g., Chipping Sparrow) from the treatment transect. At YJ, relatively few species were detected in the treatment transect potentially owing to its drier, gravel/cobble substrate. Those conditions may be more attractive to Spotted Sandpiper, which was only detected from the treatment transect (relative to control), with observations in both 2016 and 2017. If vegetation continues to establish at the YJ treatment area, we would expect Spotted Sandpiper to decline and be replaced by more forest-edge species. BAC-N treatment transect yielded many unique species (relative to the adjacent control transect). For example, Willow Flycatcher and Warbling Vireo were unique to the BAC-N treatment, which may be reflective of proximity to shrubby and treed habitats at the northern end of this site. The treatment at BAC-S contained a high richness of bird species and had the highest number of unique species (Figure 6-40). Many of these unique species are open-country and/or shrub-preferring species that may benefit from the physical works trials.

Bird nest evidence was relatively low overall, reflective of the small size of sampling areas relative to territory requirements of many breeding bird species. Valemount Peatland North is particularly suitable for higher densities of breeding bird species. As vegetation establishes on treatment plots, we expect increased use of the drawdown zone by ground or shrub-nesting birds. For example, Savannah Sparrow is expected to increase with increased cover of grasses and other low vegetation in the drawdown zone. Spotted Sandpiper may move into drawdown zone areas cleared of woody debris.

Arthropod assemblages were significantly different between treatment and control areas (blocked by year) at VP-N, YJ, and BAC-S, but not for BAC-N (Table 6-2, Table 6-4, Table 6-6, Table 6-8). As well, within treatment areas, many arthropod species are showing shifts in their relative abundance over time, potentially reflective of the ecological changes occurring at each site. One example is the ground beetle *Bembidion planatum*, which was particularly dominant in the initial post-treatment sampling. This species has been steadily declining since 2014 and was absent in samples from all sites in 2017. Another ground beetle species, *Agonum metallescens,* is associated with open sites with low vegetation cover (*Carex*, *Equisetum*, depressed grasses) and has steadily decreased since treatment application. Likewise, we have observed spider species turnover (open habitat species decreasing and transitional species increasing) in treatment plots that signals habitat transition. Given the successful establishment of shrubs and live stakes at these sites, it is expected that these taxa (and others) will replace the more open-habitat species. It should also be noted that similar increases in these taxa were observed for adjacent controls, thus turnover is potentially occurring in response to low reservoir levels since 2013.

7.0 DISCUSSION

The efficacy of physical works trials, such as wood debris removal and creation of mounds/windrows of soil and wood, are being assessed under CLBMON-11A and CLBMON-9 for enhancement of drawdown zone habitats. Post-treatment vegetation establishment has been successful in these programs (see Hawkes and Miller 2016), in contrast with earlier widespread revegetation programs conducted early in the Water Use Plan, with measurable increases in vegetation cover since treatment at all sites among the more recently revegetated areas.

Focal taxa (ground-dwelling arthropods and birds) for monitoring wildlife response to revegetation and physical works trials 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. In past reports, results have outlined the species-specific responses and pooled response across study sites within each reach. In 2017, we explore in greater detail the site-specific differences and the cumulative change in focal taxa in treatments (compared to controls) as well as inter-annual changes within each site and habitat type.

Log booms have been installed at two locations (Valemount Peatland North and Bush Arm Causeway NW) to protect each treatment area from further wood deposition. Log boom enclosures have the potential to promote natural vegetation (e.g., VP-N; Figure 6-2) and increase the probability of planted vegetation to establish (e.g., BAC-N; Figure 6-25). In the absence of a log boom enclosure, treatment areas have the potential to re-accumulate wood debris, which would negatively impact regenerating vegetation. One example of annual wood accumulation is provided by Packsaddle Creek, which was cleared of wood debris in 2014, observed to have a large amount of wood accumulation in 2015, was re-cleared in 2016, and again accumulated a substantial amount of wood on site in 2017 (Figure 7-1). Wood debris was not found to accumulate since treatment at the VP-N site (Figure 6-3), but minimal amounts did accumulate at YJ, until the site was re-cleared in 2017 (Figure 6-15).

One variable that will likely have great implications on the effectiveness of log booms enclosures is the maximum annual reservoir elevation. As stated previously, the reservoir has not reached the maximum (754.38 m ASL) since 2013 (Figure 3-1). Thus, we have yet to truly measure the efficacy of log booms for exclusion of wood accumulation in high-water years.

Likewise, the lack of high reservoir elevations and lesser inundation of treatment areas (which occur between 750.28 and 754.14 m ASL) in our post-treatment monitoring makes it difficult to truly assess the success of vegetation and taxon responses under years of higher reservoir inundation. We observed increases in vegetation cover in both control and treatment areas over the duration of our study, which suggests that the reservoir operation (longer growth season, more available terrestrial habitat, lower flooding period) is a likely driver of increased natural revegetation at all study sites. Similarly, where taxon responses are noted for the treatment areas, they were often mirrored for the adjacent control areas. Thus, the extent to which treatment application has contributed to increased vegetation and taxon responses is uncertain at this time. A comparison with monitoring occurring after a full pool reservoir cycle would be needed to assess these responses in relation to treatment efficacy.

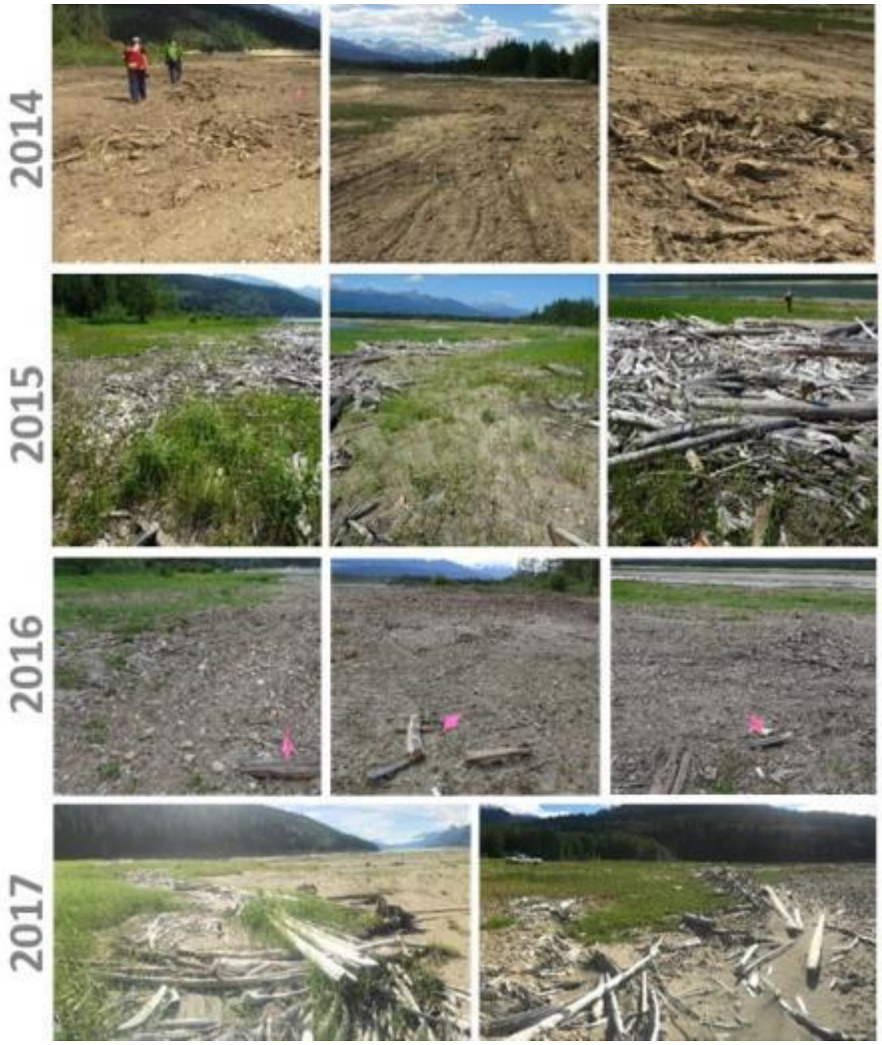

Figure 7-1: Photo documentation of wood clearing and subsequent wood accumulation at Packsaddle Creek, observed from 2014 - 2017. This site was initially cleared of wood in 2014, with additional clearing in 2016. 2015 and 2017 photos illustrate the amount of wood accumulation after one inundation cycle, post-treatment. No log boom was installed at this site.

In terms of response metrics for CLBMON-11A, relative abundance, species richness, and diversity of birds and arthropods do not appear to be informative metrics for monitoring post-treatment taxon responses. The number of species observed at a site is not always reflective of habitat quality or the desired trajectory of change. These metrics disregard the identity of particular species occurring within study areas. Since species habitat-use is determined by individual natural histories, and metrics like relative abundance, richness, and diversity do not take into account species identities, these metrics are less sensitive for determining taxon response than compositional analyses.

While results have been variable for arthropod and bird abundance, richness, and diversity over time, we are consistently finding that differences in species composition, and species-specific patterns in turnover are most reflective of the ecological changes occurring in study sites. For example, the ground beetle *Bembidion planatum* and thin-legged wolf spider *Pardosa moesta* are most abundant in open habitats with bare ground and were dominant in treatments cleared of wood in the initial monitoring year (2014). Since the initial wood removal, these species have steadily declined and *B. planatum* was no longer collected in 2017. Many other arthropod taxa were highlighted as increasing or decreasing over the past three to four years of monitoring.

Of the songbird species using the drawdown zone, Savannah Sparrow is relatively common, and is expected to colonize treatment areas where dense grass or sedge occurs. Over time, other sparrow (e.g., Chipping Sparrow) and warbler species would be expected to colonize treatment areas if a shrub layer develops, which is most likely to happen at the upper elevations of the drawdown zone (i.e., >753 m ASL). Whether post-treatment vegetation establishment effects bird communities is yet to be determined.

Site-specific differences in ground substrate (moisture and amount of organic matter), vegetation types present (shrubs, herbs), proximity to forest edge, time since treatment (1 to 4 years), and treatment type (log boom or mounding), confounds the assessment of differences between control and treatment plots when sites are considered in aggregate. For this reason, sites were assessed on an individual basis. Inter-annual variation in species richness and diversity within reference sites indicates that bird communities are not static, even in relatively stable habitats (e.g., mature forests) (for a causal example see Saether et al. 2016). This variation applied in the drawdown zone may mask trends related to revegetation prescription effectiveness. The lack of replication (due to small areas of revegetation prescriptions) and low bird density in the drawdown zone also limited our ability to make inferences. As per previous years, evidence of nesting was generally low in all study plots, which may reflect the small size of the plots relative to territory requirements of many breeding bird species. However, certain areas, such as Valemount Peatland North, support greater numbers of breeding birds due to larger vegetated areas in proximity. If vegetation establishes on treatment plots, the number of territories and nests of bird species is expected to increase, though differences may be small given the size of prescription areas. It is clear that birds are nesting within the drawdown zone, both in heavily vegetated (e.g., Savannah Sparrow) and more open (e.g., Spotted Sandpiper) areas. Revegetation prescriptions that encourage the development of grasses, sedges, and/or shrubs are also predicted to increase foraging opportunities for most species that utilize the drawdown zone.

Maintaining the integrity of treatment and control plots is important to achieve the goals of this monitoring program. The loss of treatment and control plots at Packsaddle Creek in 2016 (clearing of two treatment areas and two control areas) compromised our study design in terms of studying birds as focal taxa (since sites were used as replicates). In 2017, we found that the treatment area at Yellowjacket creek was re-cleared of wood just prior to wildlife monitoring. Uncertain stability of experimental plots may influence future monitoring, particularly when these plots are re-treated, or controls are treated. Better coordination between physical works programs and effectiveness monitoring programs is needed.

7.1 Management Questions

The management questions as written in the original 2008 Terms of Reference (ToR) were intended to assess the efficacy of the revegetation prescriptions applied under CLBWORKS-1 between 2008 and 2011 to enhance wildlife habitat in the drawdown zone. However, and as reported in Hawkes et al (2013), the revegetation prescriptions applied in the drawdown zone failed. One area (Bear

Island) that was treated in 2013 continues to survive, but it is not currently a focus of CLBMON-11A. In addition, the original monitoring program involved seasonal wildlife surveys of small mammals, ungulates, birds, arthropods, amphibians and reptiles, some of which were not appropriate taxa for the spatial scale over which treatments were applied. In June 2017, these ToR were revised, which align better with the current program taxa and treatment applications.

The current status of our ability to answer each of the four original management questions associated with CLBMON-11A is summarized below. We have responded to each question by referencing current data, which were collected to assess the efficacy of certain physical works (wood debris removal, log boom installation, and mound creation) to enhance the suitability of the drawdown zone for wildlife. In our responses to the following management questions, “revegetation program” will be expanded to include physical works trials.

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?

The revegetation program (areas planted prior to 2013) was not successful. Results of CLBMON-9 (Hawkes et al. 2013b), showed no difference between revegetation areas and adjacent controls in terms of per cent cover of vegetation, species richness, or species diversity within any plant community, elevation band, or region of Kinbasket Reservoir. Consequently, results of CLBMON-11A over these years also found no evidence for habitat enhancement or increased wildlife utilization in revegetated areas (Hawkes et al. 2014). Because previous monitoring work indicated that these initial treatments had failed to establish, this reduced the need for continued monitoring at revegetation treatment sites, and in 2014, the focus of CLBMON-11A shifted to effectiveness monitoring of physical works trials.

Amphibians are currently being monitored (under CLBMON-37 and CLBMON-58) at two locations associated with physical works: Valemount Peatland and the Bush Arm Causeway. During physical works implementation in 2014 and 2015, a number of ponds were cleared of wood debris resulting in increased use of these ponds by Western Toad and Columbia Spotted Frog. In addition to increased breeding at these cleared ponds, Hawkes (2016a) also reported growth of wetland vegetation in these ponds that were previously devoid of macrophytes. While promising, it is unclear whether the removal of wood from ponds in the drawdown zone will result in long-term habitat creation/restoration in the drawdown zone. This is because Kinbasket Reservoir has not been filled since the physical works were completed. Although the sites at the Valemount Peatland and Bush Arm Causeway were protected with log booms, the influence of reservoir operations (specifically achieving full pool) have yet to be assessed.

Currently, bird abundance appears similar (low) in the control and treatment plots; however, it is too early to tell whether the treatments are proving effective. For some species, like Savannah Sparrow, increased use is expected to occur with increased vegetation cover and area devoid of wood debris. However, we don't know if those areas cleared of wood will develop vegetation communities that will benefit bird populations long-term. It is possible that creating suitable habitat for birds in the drawdown zone could create an ecological trap due to inundation from reservoir operations, though previous studies on this in the Arrow Lakes Reservoir are mixed (van Oort et al. 2015; Hepp et al. 2018).

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?

Previous monitoring of revegetation treatment areas found no difference in arthropod relative abundance or biomass between treatment and control transects (Hawkes et al. 2014).

We are currently monitoring the abundance of beetles and spiders at each site and physical works trial treatment type. Overall, the relative abundance of these arthropods has increased at treatment and control sites since treatment implementation. We surmise that these local increases in arthropod abundance are due to the natural revegetation of both treatment and control areas in response to lower reservoir maxima (and shorter inundation period of upper elevation bands), relative to 2012 and 2013 reservoir levels. 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. Our data of ground-dwelling arthropods (spiders and beetles) show that abundance patterns are variable between years, sites, and treatments and seem to be less related to physical works trials, since similar patterns are observed in controls. Rather than monitoring an overall increase in relative abundance of arthropods, composition and species-specific responses are proving more informative for monitoring ecosystem change over time.

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?

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. The recent results of CLBWORKS-1 (Hawkes 2017) suggest that clearing ponds in the drawdown zone of wood debris improves habitat suitability for pond-breeding amphibians (e.g., Western Toad) and the results of CLBMON-37 (Hawkes et al. 2016, draft) report on the continued use of the drawdown zone by amphibians. There is no indication that revegetation efforts applied under CLBWORKS-1 between 2008 and 2011 negatively affected amphibians. However, the recent implementation of physical works prescriptions (in 2014 and 2015) precludes the detection of trends that would address this management question, thus this management question has been removed from the 2017 ToR and will not be included in future CLBMON-11A annual reports.

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

Hawkes et al. (2013b) concluded that all sedge plug and live stake plantings conducted across Kinbasket Reservoir in 2008 to 2011 were unsuccessful. Sedge plug survivorship declined from approximately 40 per cent in the two years following planting, to < 10 per cent three years post-planting, to less than five per cent four to five years post-planting. Live stakes of deciduous shrubs (willows, alder, and cottonwood) appear to have fared worse, with none found surviving five years after planting.

Our response to this question is based on an assessment of log boom installation, mound creation, and wood debris removal in the drawdown zone and not on the revegetation prescriptions applied under CLBWORKS-1 between 2008 and 2011. Based on the results obtained thus far for CLBMON-11A, it appears that woody debris removal has the potential to enhance and increase the utilization of wildlife habitat in the drawdown zone, particularly when treatment plots are fitted with an enclosure to exclude further wood deposition. Results from vegetation surveys (CLBMON-9) 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 in sites not protected by log boom installation. In addition, we have not been able to assess whether vegetation will be sustained in years where the reservoir reaches full pool, as all monitoring years since wood removal, mound creation, and log boom installation have not seen reservoir levels at the maximum. Thus, any positive effects observed in early years post-treatment may be short-lived, given long-term uncertainty in wood accumulation and reservoir impacts on vegetation in the upper elevation bands under study.

As stated earlier in the discussion, the two sites with log boom enclosures seem to promote natural revegetation (Figure 6-2) and increase the probability of planted vegetation to establish (Figure 6-25). In the absence of a log boom enclosure, treatment areas have the potential to re-accumulate wood debris, which would negatively impact regenerating vegetation (Figure 7-1). Wood debris was not found to accumulate since treatment at the VP-N site (Figure 6-3), while minimal amounts accumulated at YJ (where no log boom has been installed). As stated previously, we cannot truly assess the efficacy of log booms for exclusion of wood accumulation until monitoring is conducted in years following full-pool reservoir elevations.

Debris mounds have established vegetation growth, both from transplants and natural colonization (Figure 6-25, Figure 6-37), increased topographic heterogeneity within site, and have the potential for increase in wildlife populations (e.g., small mammal and mesocarnivore populations, Sullivan et al. 2017). We have not found any direct response of birds or arthropods to the mounds, however, if these improve the success of live stakes and shrubs in treatment areas, then they will provide generally favorable site conditions.

Wood removal success has been site-specific, in terms of long-term value to drawdown zone habitats. At sites such as Packsaddle Creek where wood debris regularly accumulates after each inundation event (Figure 7-1), wood removal as a technique on its own has limited utility to wildlife habitat. In other sites, where annual wood accumulation has not occurred (e.g., Valemount Peatland North, log boom) or has been minimal (e.g., Yellowjacket Creek, no log boom), vegetation has quickly established. Revegetation following wood debris appears to be most successful in sites with conditions like Valemount Peatland North, with rich, organic soils and higher site moisture (compared to Packsaddle Creek and Yellowjacket Creek). Thus, the success of this technique to enhance wildlife habitat in the drawdown zone depends in part on site soil characteristics and the probability of subsequent wood accumulation.

Monitoring under CLBMON-11A is currently scheduled to continue in 2018. The following is a summary of the recommendations made for the implementation of CLBMON-11A in future years:

RECOMMENDATIONS

1. **Increase sampling scope to include additional treatment areas.** The successful revegetation treatment area at Km 88 in Bush Arm and the wood removal area in the vicinity of pond 12 in Canoe Reach (completed January 2018) would be beneficial to study, in particular the efficacy of revegetation and physical works treatments in additional study areas. We recommend adopting bird surveys, nest searching, and arthropod sampling at these sites in 2018.
2. **Reduce focus on reporting results of relative abundance, richness, and diversity.** These are convenient and simple metrics, yet they are not the most useful in monitoring fauna responses to habitat change, particularly for diverse taxa, such as arthropods and birds. Reducing the response of all species into these metrics limits our ability to assess the change in species identities relative to ecosystem changes. Over the past 4 years of monitoring, we have consistently found assemblage composition and species-specific responses more informative in reflecting the changing conditions of treatment plots. Thus, we propose that while these metrics will still be reported on, they should be supported by more suitable response measures.
3. **Ensure experimental monitoring sites are maintained for the remainder of the program.** In 2016, two sites were re-treated along with the adjacent control plots at these sites (Packsaddle Creek: PS-S, PS-N), being cleared of all wood debris. In 2017, the treatment area at Yellowjacket Creek was re-cleared of wood debris, immediately prior to our wildlife sampling. It is important to minimize potential effects of site disturbance on target taxa, which may obscure results and compromise effectiveness monitoring. This will require increased coordination between programs like CLBMON-11A and CLBWORKS-16.

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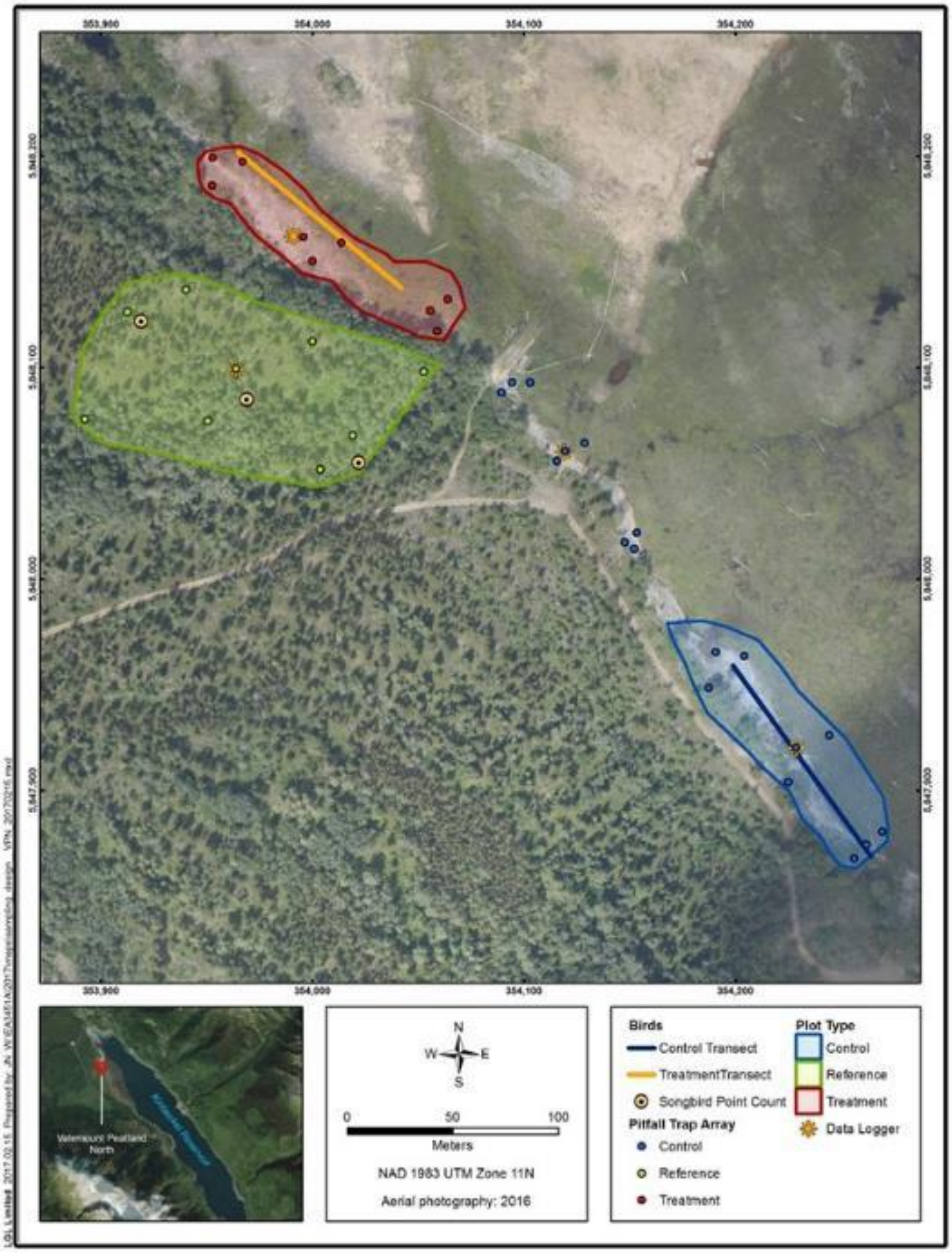
APPENDICES

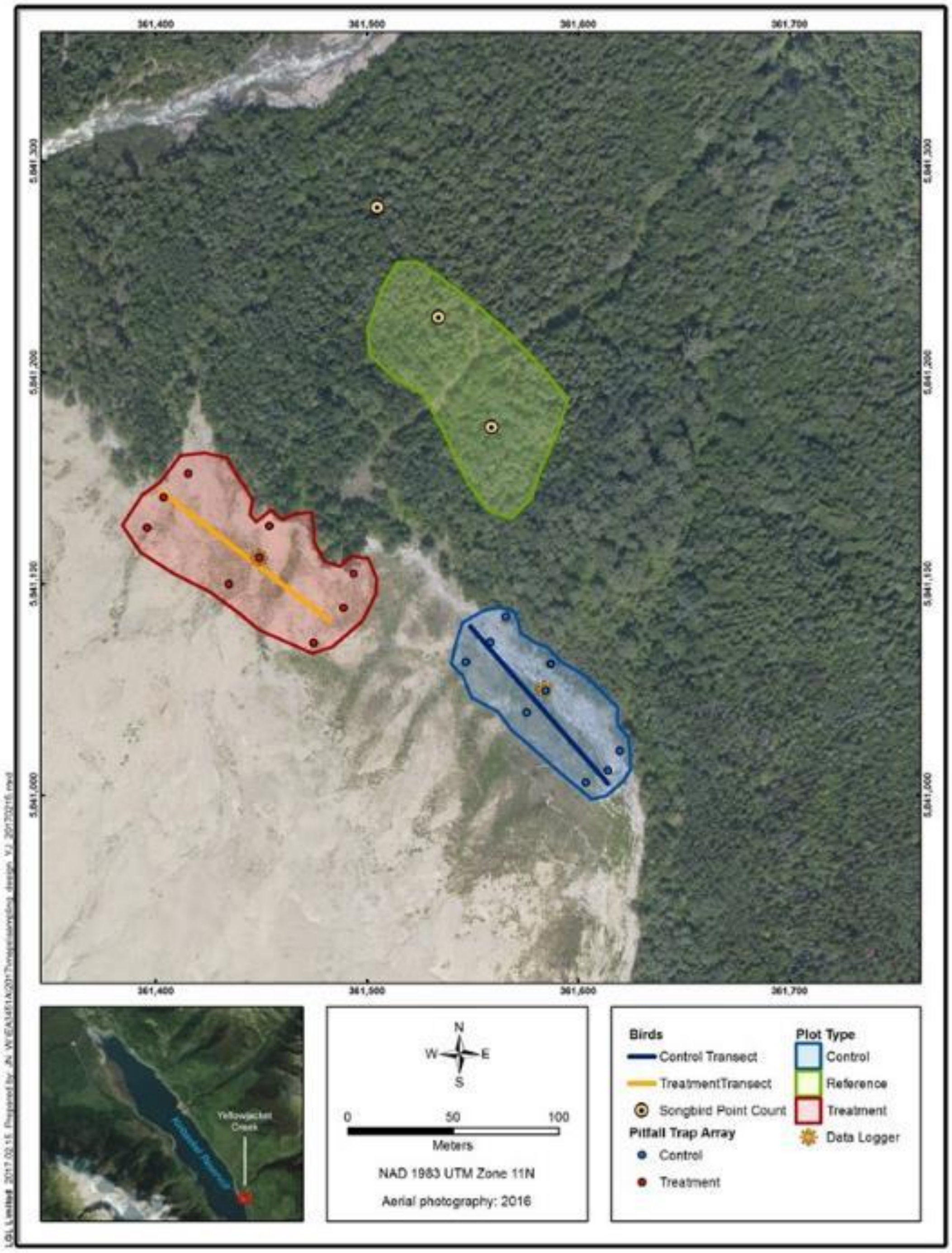
Appendix A: List of sites sampled under CLBMON-11A from 2008 to 2013. "X" = all taxa surveyed. "U" = only ungulate pellet plots. "N" = not sampled. Source: Hawkes et al. 2014.

Reach	Site #	2013 Site Name	Revegetation Treatment	Treatment Status	2008	2009	2010	2011	2012	2013
Canoe Reach	2				X	X	X	U	U	
	8	Valemount Peatland	PS/Seed		X	X	X	U	U	X
	9			Failed	X	X				
	12	Dave Henry Creek	PS		X	X	X	U	U	X
	15	Yellowjacket Creek	PS		X	X	X	U	U	X
	25	Ptarmigan Creek	LS/PS		X	X	X	U	U	N
	32		None	NA	X					
	33			Failed	X	X				
	34		PS	Failed		X				
Bush Arm	80	KM 88								X
	83				X	N	X	U	U	
	84				X	X	X	U	U	
	85			Failed		X				
	87	Hope Creek	PS		X	X	X	U	U	X
	88	Goodfellow Creek	LS/PS		X	X	X	U	U	X
	88b		Site Removed from 11-A study in 2009	NA	X					
	91		None	NA	X	X				
	121	Causeway	LS				X	U	U	X
Total					14	13	10	10	10	7

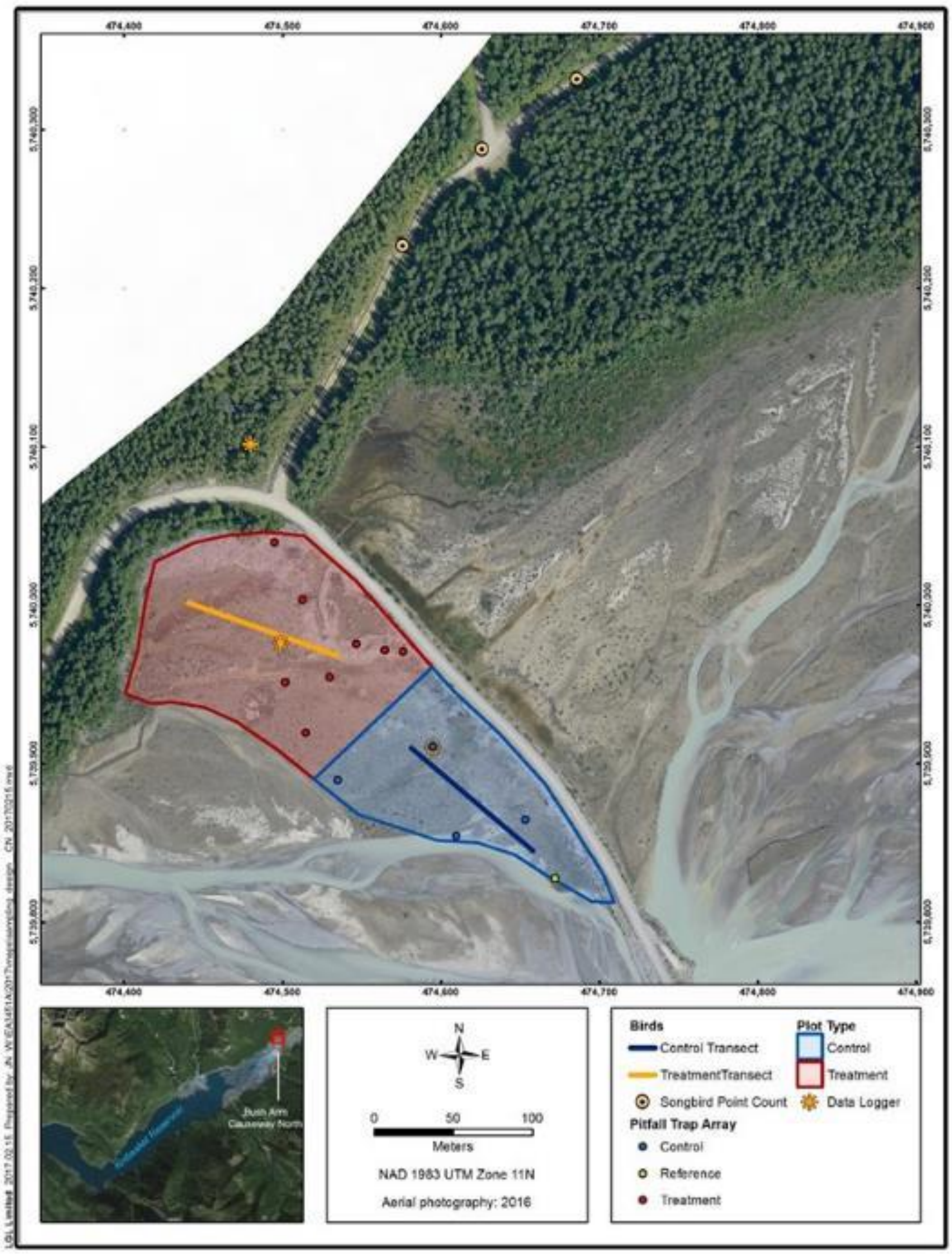
Appendix B: Maps of sampling locations during the 2017 monitoring period



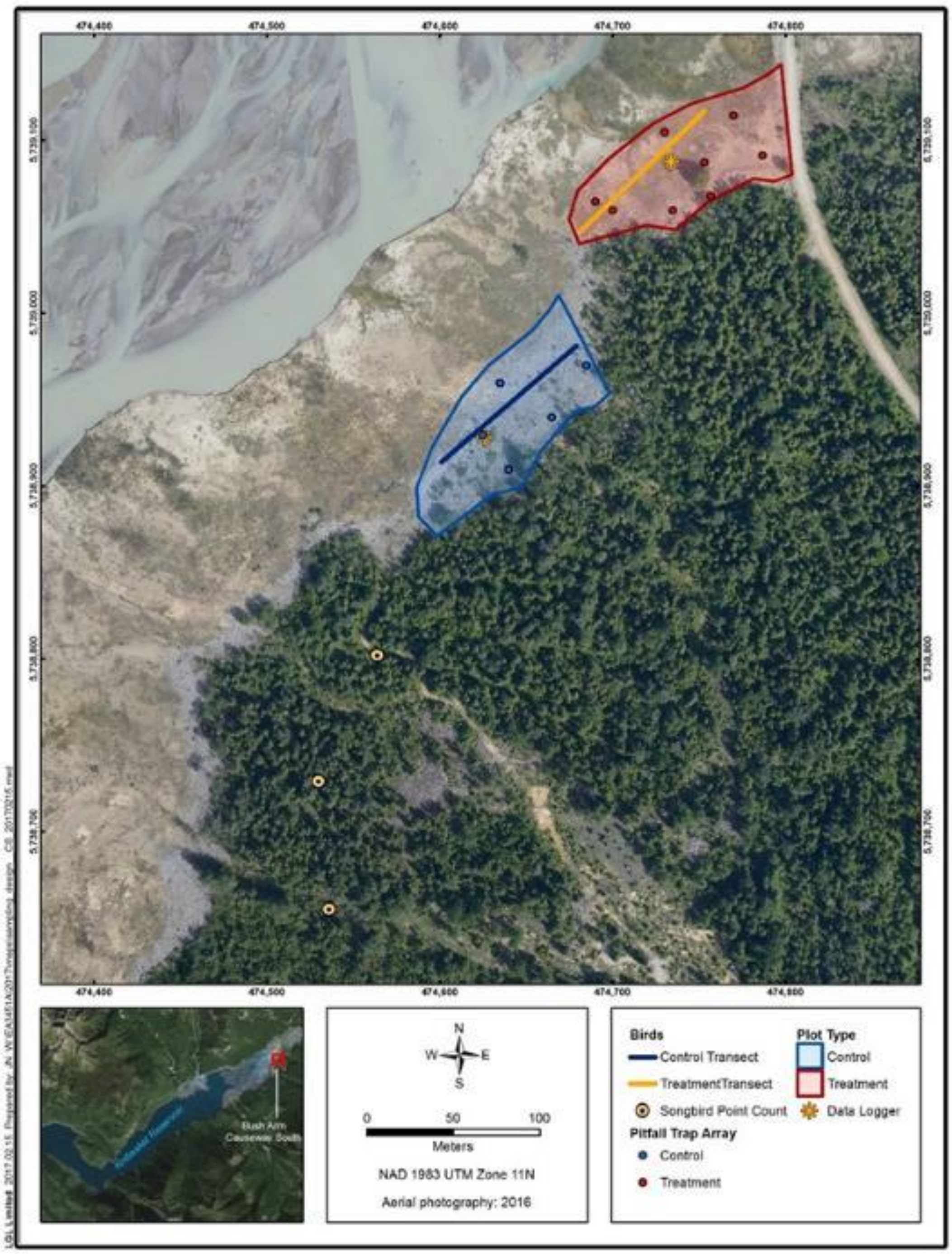
Map 1: Sampling locations at Valemount Peatland North site in 2017



Map 2: **Sampling locations at Yellowjacket Creek site in 2017**



Map 3: **Sampling locations at Bush Arm Causeway NW site in 2017**



Map 4: **Sampling locations at Bush Arm Causeway SW site in 2017**

Appendix C: Bird group, species name, code, and number of observations of all birds detected at all distances during 2017 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	
Upland Game Birds:				
Ruffed Grouse	RUGR	5	1	
Loons:				
Common Loon	COLO			1
Hawks, Eagles, Falcons and Allies:				
Bald Eagle	BAEA			1
Osprey	OSPR		1	
Shorebirds, Gulls, Auks and Allies:				
Killdeer	KILL		2	2
Spotted Sandpiper	SPSA	3	4	6
Wilson's Snipe	WISN	5		
Swifts and Hummingbirds:				
Rufous Hummingbird	RUHU	2		
Kingfishers and Allies:				
Belted Kingfisher	BEKI	1		1
Woodpeckers and Allies:				
Red-naped Sapsucker	RNSA	1		
Northern Flicker	NOFL	7	1	
Hairy Woodpecker	HAWO	3		2
Pileated Woodpecker	PIWO	1	2	
Songbirds:				
Willow Flycatcher	WIFL			2
Least Flycatcher	LEFL			1
Hammond's Flycatcher	HAFL	21		2
Dusky Flycatcher	DUFL	20	8	9
Warbling Vireo	WAVI	50	6	7
Red-eyed Vireo	REVI	3	2	
American Crow	AMCR			1
Common Raven	CORA	9	1	2
Tree Swallow	TRSW		2	1
Northern Rough-winged Swallow	NRWS	2	2	2
Black-capped Chickadee	BCCH	5		1
Red-breasted Nuthatch	RBNU	20	1	
Brown Creeper	BRCR	1		
Pacific Wren	PAWR	6		1
Golden-crowned Kinglet	GCKI	9		1
Ruby-crowned Kinglet	RCKI	9		
Mountain Bluebird	MOBL	1		2
Swainson's Thrush	SWTH	52	3	5

Bird Group: Common Name	Code	Number Observed (all distances)		
		R	C	T
Hermit Thrush	HETH	8		2
American Robin	AMRO	22	10	7
Varied Thrush	VATH	2		
American Pipit	AMPI	1		
Cedar Waxwing	CEWA	4		2
Tennessee Warbler	TEWA	39	12	11
Orange-crowned Warbler	OCWA	3	4	1
MacGillivray's Warbler	MACW	7	2	2
Common Yellowthroat	COYE	1	8	5
American Redstart	AMRE	45	10	10
Magnolia Warbler	MGNW	11	2	3
Yellow-rumped Warbler	YRWA	35	3	4
Yellow Warbler	YEWA	4		2
Wilson's Warbler	WIWA	3		1
Chipping Sparrow	CHSP	29	17	13
Clay-colored Sparrow	CCSP		4	3
Savannah Sparrow	SAVS		7	10
Song Sparrow	SOSP	3		2
Lincoln's Sparrow	LISP	3	16	10
Northern Waterthrush	NOWA	1	2	
White-throated Sparrow	WTSP	1	1	1
Dark-eyed Junco	DEJU	6	1	3
Western Tanager	WETA	2	2	1
Western Meadowlark	WEME			1
White-winged Crossbill	WWCR	1		
Pine Siskin	PISI	8	2	
Evening Grosbeak	EVGR	1	1	

Appendix D: Arthropod taxon names and species codes, for all years (2014-2017).

ORDER	FAMILY	GENUS	SPECIES	sppcode
Araneae	Agelenidae	*Agelenopsis*	*utahana*	A-Agel.utah
Araneae	Amaurobiidae	*Cybaeopsis*	*euopla*	A-Cyba.euop
Araneae	Amaurobiidae	*Cybaeopsis*	*wabritaska*	A-Cyba.wabr
Araneae	Araneidae	*Cyclosa*	*conica*	A-Cycl.coni
Araneae	Clubionidae	*Clubiona*	*canadensis*	A-Club.cana
Araneae	Clubionidae	*Clubiona*	*furcata*	A-Club.furc
Araneae	Clubionidae	*Clubiona*	*kastoni*	A-Club.kast
Araneae	Clubionidae	*Clubiona*	*kulczynskii*	A-Club.kulc
Araneae	Clubionidae	*Clubiona*	*norvegica*	A-Club.norv
Araneae	Cybaeidae	*Cybaeus*	*morosus*	A-Cyba.moro
Araneae	Dictynidae	*Argenna*	*obesa*	A-Arge.obes
Araneae	Dictynidae	*Dictyna*	*coloradensis*	A-Dict.colo
Araneae	Dictynidae	*Emblyna*	*annulipes*	A-Embl.annu
Araneae	Dictynidae	*Hackmania*	*prominula*	A-Hack.prom
Araneae	Gnaphosidae	*Callilepis*	*pluto*	A-Call.plut
Araneae	Gnaphosidae	*Drassodes*	*neglectus*	A-Dras.negl
Araneae	Gnaphosidae	*Gnaphosa*	*microps*	A-Gnap.micr
Araneae	Gnaphosidae	*Gnaphosa*	*muscorum*	A-Gnap.musc
Araneae	Gnaphosidae	*Gnaphosa*	*parvula*	A-Gnap.parv
Araneae	Gnaphosidae	*Haplodrassus*	*eunis*	A-Hapl.euni
Araneae	Gnaphosidae	*Haplodrassus*	*hiemalis*	A-Hapl.hiem
Araneae	Gnaphosidae	*Haplodrassus*	*signifer*	A-Hapl.sign
Araneae	Gnaphosidae	*Micaria*	*aenea*	A-Mica.aene
Araneae	Gnaphosidae	*Micaria*	*constricta*	A-Mica.cons
Araneae	Gnaphosidae	*Micaria*	*pulicaria*	A-Mica.puli
Araneae	Gnaphosidae	*Micaria*	*rossica*	A-Mica.ross
Araneae	Gnaphosidae	*Micaria*	*utahana*	A-Mica.utah
Araneae	Gnaphosidae	*Orodrassus*	*canadensis*	A-Orod.cana
Araneae	Gnaphosidae	*Sergiolus*	*montanus*	A-Serg.mont
Araneae	Gnaphosidae	*Zelotes*	*exiguoides*	A-Zelo.exig
Araneae	Gnaphosidae	*Zelotes*	*fratris*	A-Zelo.frat
Araneae	Gnaphosidae	*Zelotes*	*puritanus*	A-Zelo.puri
Araneae	Hahniidae	*Antistea*	*brunnea*	A-Anti.brun
Araneae	Hahniidae	*Cryphoeca*	*exlineae*	A-Cryp.exli
Araneae	Hahniidae	*Hahnia*	*arizonica*	A-Hahn.ariz
Araneae	Hahniidae	*Hahnia*	*cinerea*	A-Hahn.cine
Araneae	Hahniidae	*Neoantistea*	*agilis*	A-Neoa.agil
Araneae	Hahniidae	*Neoantistea*	*magna*	A-Neoa.magn
Araneae	Linyphiidae	*Agyneta*	*allosubtilis*	A-Agyn.allo
Araneae	Linyphiidae	*Agyneta*	*danielbelangeri*	A-Agyn.dani
Araneae	Linyphiidae	*Agyneta*	*fabra*	A-Agyn.fabr
Araneae	Linyphiidae	*Agyneta*	*lophophor*	A-Agyn.loph
Araneae	Linyphiidae	*Agyneta*	*olivacea*	A-Agyn.oliv
Araneae	Linyphiidae	*Agyneta*	*protrudens*	A-Agyn.prot
Araneae	Linyphiidae	*Agyneta*	*simplex*	A-Agyn.simp
Araneae	Linyphiidae	*Aphileta*	*misera*	A-Aphi.mise
Araneae	Linyphiidae	*Bathyphantes*	*brevipes*	A-Bath.brev
Araneae	Linyphiidae	*Bathyphantes*	*pallidus*	A-Bath.pall
Araneae	Linyphiidae	*Caviphantes*	*saxetorum*	A-Cavi.saxe
Araneae	Linyphiidae	*Ceraticelus*	*fissiceps*	A-Cera.fiss
Araneae	Linyphiidae	*Ceratinella*	*brunnea*	A-Cera.brun
Araneae	Linyphiidae	*Cnephalocotes*	*obscurus*	A-Cnep.obsc
Araneae	Linyphiidae	*Collinsia*	*ksenia*	A-Coll.ksen
Araneae	Linyphiidae	*Diplocentria*	*bidentata*	A-Dipl.bide
Araneae	Linyphiidae	*Diplocentria*	*rectangulata*	A-Dipl.rect
Araneae	Linyphiidae	*Dismodicus*	*decemoculatus*	A-Dism.dece
Araneae	Linyphiidae	*Erigone*	*aletris*	A-Erig.alet
Araneae	Linyphiidae	*Erigone*	*atra*	A-Erig.atra
Araneae	Linyphiidae	*Erigone*	*blaesa*	A-Erig.blae
Araneae	Linyphiidae	*Erigone*	*dentigera*	A-Erig.denti
Araneae	Linyphiidae	*Erigone*	*dentosa*	A-Erig.dento
Araneae	Linyphiidae	*Eulaira*	*arctoa*	A-Eula.arct
Araneae	Linyphiidae	*Eulaira*	*obscura*	A-Eula.obsc

ORDER	FAMILY	GENUS	SPECIES	sppcode
Araneae	Linyphiidae	*Frederickus*	*wilburi*	A-Fred.wilb
Araneae	Linyphiidae	*Gnathonarium*	*taczanowskii*	A-Gnat.tacz
Araneae	Linyphiidae	*Grammonota*	*angusta*	A-Gram.angu
Araneae	Linyphiidae	*Grammonota*	*gigas*	A-Gram.giga
Araneae	Linyphiidae	*Hilaira*	*canaliculata*	A-Hila.cana
Araneae	Linyphiidae	*Hypselistes*	*florens*	A-Hyps.flor
Araneae	Linyphiidae	*Incestophantes*	*mercedes*	A-Ince.merc
Araneae	Linyphiidae	*Islandiana*	*flaveola*	A-Isla.flav
Araneae	Linyphiidae	*Kaestneria*	*pullata*	A-Kaes.pull
Araneae	Linyphiidae	*Lepthyphantes*	*alpinus*	A-Lept.alpi
Araneae	Linyphiidae	*Lepthyphantes*	*intricatus*	A-Lept.intr
Araneae	Linyphiidae	*Lepthyphantes*	*turbatrix*	A-Lept.turb
Araneae	Linyphiidae	*Macrargus*	*multesimus*	A-Macr.mult
Araneae	Linyphiidae	*Maso*	*sundevalli*	A-Maso.sund
Araneae	Linyphiidae	*Mermessus*	*trilobatus*	A-Merm.tril
Araneae	Linyphiidae	*Microlinyphia*	*mandibulata*	A-Micr.mand
Araneae	Linyphiidae	*Microneta*	*viaria*	A-Micr.viar
Araneae	Linyphiidae	*Neriene*	*digna*	A-Neri.dign
Araneae	Linyphiidae	*Neriene*	*radiata*	A-Neri.radi
Araneae	Linyphiidae	*Oedothorax*	*alascensis*	A-Oedo.alas
Araneae	Linyphiidae	*Oedothorax*	*trilobatus*	A-Oedo.tril
Araneae	Linyphiidae	*Oreonetides*	*filicatus*	A-Oreo.fili
Araneae	Linyphiidae	*Oreonetides*	*flavus*	A-Oreo.flav
Araneae	Linyphiidae	*Oreonetides*	*rectangulatus*	A-Oreo.rect
Araneae	Linyphiidae	*Oreonetides*	*rotundus*	A-Oreo.rotu
Araneae	Linyphiidae	*Oreophantes*	*recurvatus*	A-Oreo.recu
Araneae	Linyphiidae	*Pelecopsis*	*mengei*	A-Pele.meng
Araneae	Linyphiidae	*Pelecopsis*	*moesta*	A-Pele.moes
Araneae	Linyphiidae	*Pelecopsis*	*sculpta*	A-Pele.scul
Araneae	Linyphiidae	*Pelecopsis*	*moesta*	A-Pele.moes
Araneae	Linyphiidae	*Pityohyphantes*	*costatus*	A-Pity.cost
Araneae	Linyphiidae	*Pityohyphantes*	*cristatus*	A-Pity.cris
Araneae	Linyphiidae	*Pocadicnemis*	*americana*	A-Poca.amer
Araneae	Linyphiidae	*Pocadicnemis*	*pumila*	A-Poca.pumi
Araneae	Linyphiidae	*Porrhomma*	*convexum*	A-Porr.conv
Araneae	Linyphiidae	*Praestigia*	*kulczynskii*	A-Prae.kulc
Araneae	Linyphiidae	*Saaristoa*	*sammamish*	A-Saar.samm
Araneae	Linyphiidae	*Sciastes*	*truncatus*	A-Scia.trun
Araneae	Linyphiidae	*Scotinotylus*	*exsectoides*	A-Scot.exse
Araneae	Linyphiidae	*Scotinotylus*	*kenus*	A-Scot.kenu
Araneae	Linyphiidae	*Scotinotylus*	*pallidus*	A-Scot.pall
Araneae	Linyphiidae	*Scotinotylus*	*sanctus*	A-Scot.sanc
Araneae	Linyphiidae	*Scyletria*	*inflata*	A-Scyl.infl
Araneae	Linyphiidae	*Sisicottus*	*montanus*	A-Sisi.mont
Araneae	Linyphiidae	*Sisicottus*	*nesides*	A-Sisi.nesi
Araneae	Linyphiidae	*Sisicottus*	*orites*	A-Sisi.orit
Araneae	Linyphiidae	*Sisicottus*	*panopeus*	A-Sisi.pano
Araneae	Linyphiidae	*Sisicus*	*penifusifer*	A-Sisi.peni
Araneae	Linyphiidae	*Spirembolus*	*monticolens*	A-Spir.mont
Araneae	Linyphiidae	*Styloctetor*	*compar*	A-Styl.comp
Araneae	Linyphiidae	*Styloctetor*	*stativus*	A-Styl.stat
Araneae	Linyphiidae	*Symmigma*	*minimum*	A-Symm.mini
Araneae	Linyphiidae	*Tapinocyba*	*minuta*	A-Tapi.minu
Araneae	Linyphiidae	*Tenuiphantes*	*zelatus*	A-Tenu.zela
Araneae	Linyphiidae	*Tunagyna*	*debilis*	A-Tuna.debi
Araneae	Linyphiidae	*Walckenaeria*	*atrotibialis*	A-Walc.atro
Araneae	Linyphiidae	*Walckenaeria*	*castanea*	A-Walc.cast
Araneae	Linyphiidae	*Walckenaeria*	*directa*	A-Walc.dire
Araneae	Linyphiidae	*Walckenaeria*	*exigua*	A-Walc.exig
Araneae	Linyphiidae	*Walckenaeria*	*subspiralis*	A-Walc.subs
Araneae	Linyphiidae	*Walckenaeria*	*vigilax*	A-Walc.vigi
Araneae	Linyphiidae	*Zornella*	*armata*	A-Zorn.arma
Araneae	Liocranidae	*Agroeca*	*ornata*	A-Agro.orna
Araneae	Lycosidae	*Alopecosa*	*aculeata*	A-Alop.acul
Araneae	Lycosidae	*Arctosa*	*raptor*	A-Arct.rapt

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Araneae	Lycosidae	*Arctosa*	*rubicunda*	A-Arct.rubi
Araneae	Lycosidae	*Hogna*	*frondicola*	A-Hogn.fron
Araneae	Lycosidae	*Pardosa*	*fuscula*	A-Pard.fusc
Araneae	Lycosidae	*Pardosa*	*groenlandica*	A-Pard.groe
Araneae	Lycosidae	*Pardosa*	*lowriei*	A-Pard.lowr
Araneae	Lycosidae	*Pardosa*	*mackenziana*	A-Pard.mack
Araneae	Lycosidae	*Pardosa*	*moesta*	A-Pard.moes
Araneae	Lycosidae	*Pardosa*	*tesquorum*	A-Pard.tesq
Araneae	Lycosidae	*Pardosa*	*wyuta*	A-Pard.wyut
Araneae	Lycosidae	*Pardosa*	*xerampelina*	A-Pard.xera
Araneae	Lycosidae	*Pirata*	*piraticus*	A-Pira.pira
Araneae	Lycosidae	*Piratula*	*insularis*	A-Pira.insu
Araneae	Lycosidae	*Trochosa*	*terricola*	A-Troc.terr
Araneae	Philodromidae	*Philodromus*	*alascensis*	A-Phil.alas
Araneae	Philodromidae	*Philodromus*	*cespitum*	A-Phil.cesp
Araneae	Philodromidae	*Philodromus*	*oneida*	A-Phil.onei
Araneae	Philodromidae	*Philodromus*	*pernix*	A-Phil.pern
Araneae	Philodromidae	*Philodromus*	*placidus*	A-Phil.plac
Araneae	Philodromidae	*Philodromus*	*rufus*	A-Phil.rufu
Araneae	Philodromidae	*Thanatus*	*coloradensis*	A-Than.colo
Araneae	Philodromidae	*Thanatus*	*formicinus*	A-Than.form
Araneae	Philodromidae	*Tibellus*	*oblongus*	A-Tibe.oblo
Araneae	Phrurolithidae	*Phrurotimpus*	*borealis*	A-Phru.bore
Araneae	Phrurolithidae	*Scotinella*	*pugnata*	A-Scot.pugn
Araneae	Pisauridae	*Dolomedes*	*triton*	A-Dolo.trit
Araneae	Salticidae	*Evarcha*	*proszynskii*	A-Evar.pros
Araneae	Salticidae	*Habronattus*	*decorus*	A-Habr.deco
Araneae	Salticidae	*Neon*	*nelli*	A-Neon.nell
Araneae	Salticidae	*Pelegrina*	*flavipes*	A-Pele.flav
Araneae	Telemidae	*Usofila*	*pacifica*	A-Usof.paci
Araneae	Tetragnathidae	*Pachygnatha*	*clercki*	A-Pach.cler
Araneae	Tetragnathidae	*Tetragnatha*	*laboriosa*	A-Tetr.labo
Araneae	Tetragnathidae	*Tetragnatha*	*versicolor*	A-Tetr.vers
Araneae	Theridiidae	*Dipoena*	*nigra*	A-Dipo.nigr
Araneae	Theridiidae	*Enoplognatha*	*intrepida*	A-Enop.intr
Araneae	Theridiidae	*Enoplognatha*	*marmorata*	A-Enop.marm
Araneae	Theridiidae	*Euryopis*	*argentea*	A-Eury.arge
Araneae	Theridiidae	*Euryopis*	*formosa*	A-Eury.form
Araneae	Theridiidae	*Euryopis*	*funebris*	A-Eury.fune
Araneae	Theridiidae	*Neottiura*	*bimaculata*	A-Neot.bima
Araneae	Theridiidae	*Robertus*	*fuscus*	A-Robe.fusc
Araneae	Theridiidae	*Robertus*	*vigerens*	A-Robe.vige
Araneae	Theridiidae	*Rugathodes*	*sexpunctatus*	A-Ruga.sexp
Araneae	Theridiidae	*Steatoda*	*borealis*	A-Stea.bore
Araneae	Thomisidae	*Misumena*	*vatia*	A-Misu.vati
Araneae	Thomisidae	*Xysticus*	*benefactor*	A-Xyst.bene
Araneae	Thomisidae	*Xysticus*	*britcheri*	A-Xyst.brit
Araneae	Thomisidae	*Xysticus*	*canadensis*	A-Xyst.cana
Araneae	Thomisidae	*Xysticus*	*discursans*	A-Xyst.disc
Araneae	Thomisidae	*Xysticus*	*elegans*	A-Xyst.eleg
Araneae	Thomisidae	*Xysticus*	*ellipticus*	A-Xyst.elli
Araneae	Thomisidae	*Xysticus*	*ferox*	A-Xyst.fero
Araneae	Thomisidae	*Xysticus*	*luctuosus*	A-Xyst.luct
Araneae	Thomisidae	*Xysticus*	*montanensis*	A-Xyst.mont
Araneae	Thomisidae	*Xysticus*	*obscurus*	A-Xyst.obsc
Araneae	Thomisidae	*Xysticus*	*triguttatus*	A-Xyst.trig
Coleoptera	Carabidae	*Agonum*	*affine*	C-Agon.affi
Coleoptera	Carabidae	*Agonum*	*consimile*	C-Agon.cons
Coleoptera	Carabidae	*Agonum*	*corvus*	C-Agon.corv
Coleoptera	Carabidae	*Agonum*	*cupreum*	C-Agon.cupr
Coleoptera	Carabidae	*Agonum*	*cupripenne*	C-Agon.cupr
Coleoptera	Carabidae	*Agonum*	*gratiosum*	C-Agon.grat
Coleoptera	Carabidae	*Agonum*	*metallescens*	C-Agon.meta
Coleoptera	Carabidae	*Agonum*	*muelleri*	C-Agon.muel
Coleoptera	Carabidae	*Agonum*	*placidum*	C-Agon.plac

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Coleoptera	Carabidae	*Agonum*	*retractum*	C-Agon.retr
Coleoptera	Carabidae	*Agonum*	*simile*	C-Agon.simi
Coleoptera	Carabidae	*Agonum*	*sordens*	C-Agon.sord
Coleoptera	Carabidae	*Agonum*	*suturale*	C-Agon.sutu
Coleoptera	Carabidae	*Agonum*	*thoreyi*	C-Agon.thor
Coleoptera	Carabidae	*Amara*	*apricaria*	C-Amar.apri
Coleoptera	Carabidae	*Amara*	*sp.1*	C-Amar.cw4
Coleoptera	Carabidae	*Amara*	*familiaris*	C-Amar.fami
Coleoptera	Carabidae	*Amara*	*littoralis*	C-Amar.litt
Coleoptera	Carabidae	*Amara*	*patruelis*	C-Amar.patr
Coleoptera	Carabidae	*Amara*	*quenseli*	C-Amar.quen
Coleoptera	Carabidae	*Amara*	*schwarzi*	C-Amar.schw
Coleoptera	Carabidae	*Amara*	*sinuosa*	C-Amar.sinu
Coleoptera	Carabidae	*Amara*	*sp.2*	C-Amar.sp.x
Coleoptera	Carabidae	*Amara*	*sp.3*	C-Amar.sp.y
Coleoptera	Carabidae	*Amara*	*torrida*	C-Amar.torr
Coleoptera	Carabidae	*Bembidion*	*bimaculatum*	C-Bemb.bima
Coleoptera	Carabidae	*Bembidion*	*convexulum*	C-Bemb.conv
Coleoptera	Carabidae	*Bembidion*	*incrematum*	C-Bemb.incr
Coleoptera	Carabidae	*Bembidion*	*interventor*	C-Bemb.inte
Coleoptera	Carabidae	*Bembidion*	*kuprianovii*	C-Bemb.kupr
Coleoptera	Carabidae	*Bembidion*	*nigripes*	C-Bemb.nigr
Coleoptera	Carabidae	*Bembidion*	*obscurellum*	C-Bemb.obsc
Coleoptera	Carabidae	*Bembidion*	*petrosum*	C-Bemb.petr
Coleoptera	Carabidae	*Bembidion*	*planatum*	C-Bemb.plan
Coleoptera	Carabidae	*Bembidion*	*quadrimaculatum*	C-Bemb.quad
Coleoptera	Carabidae	*Bembidion*	*rupicola*	C-Bemb.rupi
Coleoptera	Carabidae	*Bembidion*	*sordidum*	C-Bemb.sord
Coleoptera	Carabidae	*Bembidion*	*sp.1*	C-Bemb.sp.1
Coleoptera	Carabidae	*Bembidion*	*sp.3*	C-Bemb.sp.3
Coleoptera	Carabidae	*Bembidion*	*tetracolum*	C-Bemb.tetr
Coleoptera	Carabidae	*Bembidion*	*timidum*	C-Bemb.timi
Coleoptera	Carabidae	*Bembidion*	*transparens*	C-Bemb.tran
Coleoptera	Carabidae	*Blethisa*	*hudsonica*	C-Blet.huds
Coleoptera	Carabidae	*Blethisa*	*quadricollis*	C-Blet.quad
Coleoptera	Carabidae	*Bradycellus*	*lecontei*	C-Brad.leco
Coleoptera	Carabidae	*Bradycellus*	*nigrinus*	C-Brad.nigr
Coleoptera	Carabidae	*Calathus*	*advena*	C-Cala.adve
Coleoptera	Carabidae	*Calathus*	*ingratus*	C-Cala.ingr
Coleoptera	Carabidae	*Carabus*	*taedatus*	C-Cara.taed
Coleoptera	Carabidae	*Chlaenius*	*lithophilus*	C-Chla.lith
Coleoptera	Carabidae	*Chlaenius*	*niger*	C-Chla.nige
Coleoptera	Carabidae	*Cicindela*	*longilabris*	C-Cici.long
Coleoptera	Carabidae	*Cicindela*	*oregona*	C-Cici.oreg
Coleoptera	Carabidae	*Cicindela*	*repanda*	C-Cici.repa
Coleoptera	Carabidae	*Cicindela*	*tranquebarica*	C-Cici.tran
Coleoptera	Carabidae	*Cylindera*	*terricola*	C-Cyli.terr
Coleoptera	Carabidae	*Cymindis*	*cribricollis*	C-Cymi.crib
Coleoptera	Carabidae	*Dicheirotrichus*	*cognatus*	C-Dich.cogn
Coleoptera	Carabidae	*Dyschirius*	*alticola*	C-Dysc.alti
Coleoptera	Carabidae	*Dyschirius*	*sp.1*	C-Dysc.sp.1
Coleoptera	Carabidae	*Elaphrus*	*americanus*	C-Elap.amer
Coleoptera	Carabidae	*Elaphrus*	*clairvillei*	C-Elap.clai
Coleoptera	Carabidae	*Elaphrus*	*lecontei*	C-Elap.leco
Coleoptera	Carabidae	*Harpalus*	*affinis*	C-Harp.affi
Coleoptera	Carabidae	*Harpalus*	*fulvilabris*	C-Harp.fulv
Coleoptera	Carabidae	*Harpalus*	*laevipes*	C-Harp.laev
Coleoptera	Carabidae	*Harpalus*	*laticeps*	C-Harp.lati
Coleoptera	Carabidae	*Harpalus*	*nigritarsis*	C-Harp.nigr
Coleoptera	Carabidae	*Harpalus*	*obnixus*	C-Harp.obni
Coleoptera	Carabidae	*Harpalus*	*solitaris*	C-Harp.soli
Coleoptera	Carabidae	*Harpalus*	*somnulentus*	C-Harp.somn
Coleoptera	Carabidae	*Harpalus*	*sp.1*	C-Harp.sp.1
Coleoptera	Carabidae	*Heterosilpha*	*ramosa*	C-Hete.ramo
Coleoptera	Carabidae	*Loricera*	*decempunctata*	C-Lori.dece

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Coleoptera	Carabidae	*Loricera*	*pilicornis*	C-Lori.pili
Coleoptera	Carabidae	*Miscodera*	*arctica*	C-Misc.arct
Coleoptera	Carabidae	*Nebria*	*gebleri*	C-Nebr.gebl
Coleoptera	Carabidae	*Nebria*	*obliqua*	C-Nebr.obli
Coleoptera	Carabidae	*Notiophilus*	*semistriatus*	C-Noti.semi
Coleoptera	Carabidae	*Notiophilus*	*sp.2*	C-Noti.sp.2
Coleoptera	Carabidae	*Patrobrus*	*fossifrons*	C-Patr.foss
Coleoptera	Carabidae	*Patrobus*	*fossifrons*	C-Patr.foss
Coleoptera	Carabidae	*Patrobus*	*stygicus*	C-Patr.styg
Coleoptera	Carabidae	*Platynus*	*decentis*	C-Plat.dece
Coleoptera	Carabidae	*Platynus*	*mannerheimi*	C-Plat.mann
Coleoptera	Carabidae	*Poecilus*	*lucublandus*	C-Poec.lucu
Coleoptera	Carabidae	*Pterostichus*	*adstrictus*	C-Pter.adst
Coleoptera	Carabidae	*Pterostichus*	*commutabilis*	C-Pter.comm
Coleoptera	Carabidae	*Pterostichus*	*ecarinatus*	C-Pter.ecar
Coleoptera	Carabidae	*Pterostichus*	*herculaneus*	C-Pter.herc
Coleoptera	Carabidae	*Pterostichus*	*melanarius*	C-Pter.mela
Coleoptera	Carabidae	*Pterostichus*	*neobrunneus*	C-Pter.neob
Coleoptera	Carabidae	*Pterostichus*	*patruelis*	C-Pter.patr
Coleoptera	Carabidae	*Pterostichus*	*pensylvanicus*	C-Pter.pens
Coleoptera	Carabidae	*Pterostichus*	*protractus*	C-Pter.prot
Coleoptera	Carabidae	*Pterostichus*	*riparius*	C-Pter.ripa
Coleoptera	Carabidae	*Scaphinotus*	*angusticollis*	C-Scap.angu
Coleoptera	Carabidae	*Scaphinotus*	*marginatus*	C-Scap.marg
Coleoptera	Carabidae	*Scaphinotus*	*relictus*	C-Scap.reli
Coleoptera	Carabidae	*Sericoda*	*bogemannii*	C-Seri.boge
Coleoptera	Carabidae	*Syntomus*	*americanus*	C-Synt.amer
Coleoptera	Carabidae	*Synuchus*	*impunctatus*	C-Synu.impu
Coleoptera	Carabidae	*Trechus*	*chalybeus*	C-Trec.chal
Coleoptera	Carabidae	*Trechus*	*sp.1*	C-Trec.sp.1
Coleoptera	Carabidae	*Trichocellus*	*cognatus*	C-Tric.cogn