Columbia River Project Water Use Plan

Kinbasket and Arrow Lakes Reservoir

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

Implementation Year 9

Reference: CLBMON-11B1

Final Annual Report

Study Period: 2018

Okanagan Nation Alliance, Westbank, BC

and

LGL Limited environmental research associates
Sidney, BC

April 29, 2019

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KINBASKET AND ARROW LAKES RESERVOIRS

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




Final Report 2018

Prepared for

BC Hydro

BC Hydro Generation

Water Licence Requirements
6911 Southpoint Drive
Burnaby, BC

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

EXECUTIVE SUMMARY

CLBMON-11B1, initiated in 2009, is a long-term wildlife monitoring project to assess the efficacy of revegetation prescriptions (i.e., those implemented under CLBWORKS-2) and wildlife physical works projects (i.e., those developed under CLBWORKS-29B and implemented under CLBWORKS-30), at enhancing the suitability of habitats in the drawdown zone of Arrow Lakes Reservoir for wildlife. To date, wildlife effectiveness monitoring under CLBMON-11B1 has occurred in all years since 2009, except 2012. The Terms of Reference for 11B1 were revised in June 2017, and this report is guided by the revised Management Questions.

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

Several potential wildlife physical works projects were developed under CLBWORKS-29B (Hawkes and Tuttle 2016, Hawkes and Howard 2012). A feasibility design was prepared for one location at Burton Creek under CLBWORKS-30B (Kerr Wood Leidel 2017). However, currently no wildlife physical works projects have been implemented. Burton Creek will be the first focus of future physical works effectiveness monitoring. Baseline data collection was initiated in 2017 through CLBMON-11B1 and continued in 2018.

Monitoring Approaches

The revegetation prescriptions applied in the drawdown zone may affect prey populations (i.e., terrestrial arthropods) before they affect the predators of those arthropods (songbirds and bats). Thus, since 2013 we have sampled songbirds and arthropods as focal taxa. Arthropod populations are being tracked using two collection methods (pitfall traps and Malaise traps). Responses of birds are being monitored by point count surveys and nest searches. These monitoring datasets will be used to assess the efficacy of revegetation prescriptions and future habitat enhancements applied in the drawdown zone. Supplementary bat data was collected by deploying autonomous recording units and subsequently analysing activity via automatic call classification software.

In 2018, wildlife monitoring was stratified to occur in revegetation polygons that were noted to support at least some surviving transplants (as per Miller et al. 2018). Within each site, sampling areas for arthropods and birds were limited to areas classified as follows (collectively termed "habitat types"):

1. <u>Treatment: Stake</u>. Areas of the drawdown zone that were revegetated by planting black cottonwood (*Populus trichocarpa*), willow (*Salix* sp.), and red-osier dogwood (*Cornus stolonifera*) stake prescriptions developed under CLBWORKS-2. Stake treatments were delineated in polygons.

2. Treatment: Graminoid. Areas of the drawdown zone that were revegetated by planting sedge (*Carex* sp.), rush (*Scirpus* sp.), or grass (*Calamagrostis canadensis*) seedlings during CLBWORKS-2. Graminoid treatments were delineated in polygons.
3. Control. A control was established adjacent to treatment polygons in the drawdown zone, to serve as untreated (i.e., not revegetated) controls within the study sites.

Monitoring of arthropods and birds occurred mainly within six sites with revegetation treatments: Burton Creek, Lower Inonoaklin, Edgewood South, Edgewood North, 9 Mile, and 12 Mile. Bird point counts and nest searches were also conducted at McKay Creek, 8 Mile, and East Arrow Park. Arthropod sampling occurred in stake (n=5), graminoid (n=3), and control (n=6) areas. Bird point counts were located in stake (n=18) and graminoid (n=10) polygons, and control areas for a total of 33, 19, and 19 point count stations in stake, graminoid and control areas respectively. Bats were surveyed at Burton Creek, Lower Inonoaklin, and Edgewood South, and Armstrong Lake (a non-drawdown zone reference site).

In addition, pre-treatment sampling occurred within an area proposed for Wildlife Physical Works at Burton Creek.

Revegetation effectiveness monitoring results

We found that vegetation cover was variable across study sites, and there was no clear relationship between per cent cover of live organic matter (LOM) and revegetation treatment. The results of wildlife effectiveness monitoring are likewise variable with evident site-specific effects.

Arthropods. Results were mixed for arthropod response to revegetation treatments. The effect of revegetation on arthropod CPUE and biomass varied between sites. There was no strong trend that indicated whether revegetation positively or negatively affected these measures of productivity. Similarly, for other measures of arthropod richness and diversity (including Coleoptera family diversity and Araneae species diversity), the influence of revegetation was generally negligible, and any trends that stood out were not consistent between sites. One exception is an apparently positive relationship between carabid species diversity and graminoid revegetation treatment. There was also a possible trend of increased carabid abundance (CPUE) in revegetated (both stake and graminoid) polygons compared to the controls.

Ground beetle and spider species composition were significantly influenced by an interaction of site and treatment, although the relationship was weak (<20% of the variance in assemblage composition). Main composition differences were between revegetation and control samples. No compositional differences were apparent between graminoid and live stake treatments. Neither of the species assemblages were explained by differences in per cent LOM cover. Thus, the observed effects of revegetation may be related to changes in vegetation structure, vegetation communities, or other attributes that may differ between revegetation and control polygons, rather than vegetation density.

Songbirds. There was no significant effect of revegetation on songbird species richness. However, there were site-specific patterns. Revegetated stake polygons had greater richness than controls for 8 Mile and 9 Mile. Conversely, Edgewood North had higher species richness in control than treatment polygons. Trends for species diversity were like those for species richness and there was no difference in diversity across habitat types. Community analyses for bird point counts were limited due to low species detection. Non-metric multidimensional scaling (nMDS) ordination for songbird species composition indicated similar songbird communities in each treatment type.

A total of 40 nests were found, 26 of which were in non-revegetated areas (controls and adjacent drawdown zone areas). There were eight documented nest failures, at least three (but possibly five) of which were due to inundation by rising reservoir levels. These three inundated nests were all from ground-nesting species, and occurred within graminoid treatment, stake treatment, and control areas. There were six probable nesting successes, and many unknown outcomes due to the inability to track nests through completion.

Bats. Like previous years, monitoring the use of the drawdown zone by bats resulted in the documentation of 12 species of bat occurring in mid- and lower Arrow Lakes Reservoir. Five of these species are of provincial/national conservation concern, including Townsend's Big-eared Bat (*Corynorhinus townsendii*), Western Small-footed Myotis (*Myotis ciliolabrum*), Northern Myotis (*M. septentrionalis*), Fringed Myotis (*M. thysanodes*), and Little Brown Myotis (*M. lucifugus*). Little Brown Myotis was the most frequently recorded species overall, followed by Yuma Myotis (*M. yumanensis*). Townsend's Big-eared Bat and Fringed Myotis were the most infrequently detected species.

The number of bat recordings per detector-hour (as a measure of relative activity) was highest at Lower Inonoaklin, followed by Edgewood South. The detectors at Burton Creek had the lowest bat detection rates compared to other sites. Species composition varied within and across sites. However, all sites shared a greater prevalence of *Myotis* species compared to larger bat species.

Wildlife Physical Works monitoring. In 2018 we continued to characterise the baseline, pre-treatment condition of the wildlife physical works site at Burton Creek.

We identified 26 families of Hymenoptera, 30 families of Diptera, seven families and 18 species of Araneae, 11 families of Coleoptera, and 12 species of Carabidae. Four arthropod species were noted as adventive to Canada, including one spider species (*Trochosa ruricola*) and three carabid species (*Pterostichus melanarius, Carabus granulatus,* and *Clivina fossor*). The European ground beetle *Pterostichus melanarius* was the most abundant ground beetle collected at the WPW site. This species is well-established in North America, associated with human activity and habitat alteration.

We recorded six species of songbirds from point count surveys and 92 species of birds from waterfowl surveys in the Wildlife Physical Works area in 2018. Waterfowl usage of the WPW location remained low, even during September when larger concentrations of waterfowl and other birds were noted in the Burton Creek area. Breeding bird usage of the WPW location is similarly low, with few species or individuals recorded. The baseline physical works data on bird usage is necessary as a performance measure for the wetland once fully constructed.

We recorded 11 species of bat in the Wildlife Physical Works area, which were predominately species of *Myotis*. The number of bat detections was lower at Burton Creek than other sites.

Summary. Between 2009 and 2018, Monitoring under CLBMON-11B1 has assessed the effectiveness of revegetation treatments applied in the drawdown zone of Arrow Lakes Wildlife and wildlife use of those treatments. Challenges associated with assessing revegetation success in sampling years before 2018 led to the revision of the Terms of Reference for the CLBMON-11B projects in June 2017. This report is therefore guided by the 2017 Terms of Reference and refers only to work completed in the Arrow Lakes Reservoir in 2018.

The response of arthropods and birds to revegetation have been mixed, and there is no overall obvious impact of revegetation treatment. Within- and between-site effects on arthropods and birds may be obfuscating the treatment effects of revegetation. However, with a few exceptions, both birds and arthropods seem to be using treatment sites at least to the same extent that they use control sites.

<table>
<tr><th colspan="2">Management Question (MQ)</th><th>Summary of Key Results</th></tr>
<tr><td rowspan="2">MQ1. Were the revegetation projects effective at increasing wildlife utilization or enhancing the suitability of wildlife habitat to a biologically meaningful extent?</td><td>a. How did the revegetation projects affect the productivity (measures of biomass, or reproductive success) of wildlife habitat in the drawdown zone?</td><td><u>Summary of Findings</u>

Previous multi-year trend analyses have not found any difference in arthropod biomass between revegetation treatments and controls. Likewise, results of 2018 monitoring did not find any noticeable effect of revegetation treatment on total arthropod biomass in the drawdown zone. There was no evidence that revegetation has increased bird productivity relative to untreated areas in the drawdown zone overall. Breeding birds have been noted in treated and untreated areas, with nesting success and failure from both. A few observations of birds nesting in the Black Cottonwood stake treatment area at Lower Inonoaklin suggest that the revegetation treatment at that location is providing suitable breeding habitat for some species.

<u>Sources of Uncertainty/Limitations</u>

• Due to lack of pre-treatment sampling, it is unknown if revegetation has enhanced wildlife habitat in the drawdown zone.
• Natural annual population variation and seasonality.
• Lack of replication.
• Mixed success of revegetation program.
• Variable reservoir operations.
• Physical works have not been implemented.
• Previous bi-annual sampling.
• Possible site-by-site variation.

<u>Comments</u>

While nesting productivity may have increased for a few bird species relative to the pre-revegetated condition, evidence is limited to a few observations at some sites. However, no trends in productivity in general have been noted.</td></tr>
<tr><td>b. What were the conditions at the revegetation study sites in terms of wildlife habitat suitability at the time of project initiation?</td><td><u>Summary of Findings</u>

Pre-treatment conditions were not assessed. Baseline data was not collected prior to CLBWORKS-2 treatment application.

<u>Sources of Uncertainty/Limitations</u>

• Lack of baseline data.
• Potential that treated areas were ecologically different from surrounding non-treatment areas before planting, which makes it difficult to assess treatment success.

<u>Comments</u>

It is unclear what the pre-treatment conditions were at each revegetation polygon, in terms of existing vegetation, soil stability, substrate qualities, wildlife use, or other ecologically meaningful conditions. It was noted that at least some CLBWORKS-2 plantings were selectively applied to poor areas within the drawdown zone (Enns and Overholt 2013), which makes comparison to adjacent controls problematic.</td></tr>
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<table>
<tr><th colspan="2">Management Question (MQ)</th><th>Summary of Key Results</th></tr>
<tr><td rowspan="3"></td><td></td><td></td></tr>
<tr><td>c. How did revegetation modify the area (m²) or the suitability of wildlife habitat based on: comparisons between treated and untreated areas, vegetation change over the course of the monitoring study, and available baseline data on vegetation structure?</td><td><u>Summary of Findings</u>

While approximately 106 ha of drawdown zone habitat were treated from 2008-2011 under CLBWORKS-2, revegetation efforts achieved mixed success at promoting vegetation establishment. Results from CLBMON-12 vegetation monitoring found some polygons had nil survival of plantings, while others appeared vigorous and thriving. The only significant differences in vegetation cover were found for the upper elevation band in the "redtop-upland" vegetation community type (438-440 m ASL), which had greater shrub cover than adjacent controls (Miller et al. 2018). This VCT is present for several of the selected polygons monitored for CLBMON-11B1 in 2018 (Lower Inonoaklin: 2009 18, 2011 23; Edgewood South: 2009 3; 12 Mile: 2009 87; and 9 Mile: 2010 RR). Black Cottonwood stakes may contribute to habitat suitability for shrub and tree-nesting birds at some sites by providing increased nesting opportunities within the drawdown zone for those groups.

<u>Sources of Uncertainty/Limitations</u>

• No pre-treatment data on vegetation structure within revegetation areas and adjacent controls.
• Natural annual population variation and seasonality.
• Lack of replication.
• Mixed success of revegetation program.
• Variable reservoir operations.

<u>Comments</u>

Based on the limited structural differences found between treatment areas and adjacent controls, it is unlikely that the revegetation program enhanced the suitability of wildlife habitat to a significant extent. In select areas (high elevation, redtop-upland vegetation communities), the revegetation program may have contributed to increased shrub density relative to adjacent untreated drawdown zone areas. It is currently unknown if revegetation has enhanced wildlife habitat in the drawdown zone.</td></tr>
<tr><td>d. Did revegetation affect songbird utilization of habitat as measured by species richness and/or relative abundance, based on: comparisons between revegetated and untreated areas, and/or vegetation change over the course of the monitoring study?</td><td><u>Summary of Findings</u>

Overall there was no effect of vegetation treatment on songbird utilization. Neither richness nor diversity differed between the two. The spatial scale of the revegetation polygons is limiting, and in most cases are smaller than the average territory size for ground or shrub-nesting bird species. Nests have been located in both revegetated and untreated areas of the drawdown zone, though in most cases there is no evidence that planted vegetation has been utilized specifically. The Black Cottonwood stake treatment at Lower Inonoaklin is the exception and appears to be used annually by shrub and tree-nesting species.

<u>Sources of Uncertainty/Limitations</u>

• The mobility and home range size of songbirds is incongruous with the limited spatial scale of revegetation treatments preventing quantitative analysis of treatment effects.
• Lack of baseline sampling.
• Low sample size for birds within 30 m of point count stations (at greater distances the count would sample other treated or untreated areas).</td></tr>
</table>

Management Question (MQ)		Summary of Key Results
		• Inter-annual variability, and site effects. • High reservoir levels precluding sampling of most revegetation polygons at each site. • Variation within treatment methods for revegetation treatments (species mixes, densities, fertilizer, method of planting, area selected for treating, etc.) impedes experimental design for hypothesis testing. • Natural annual population variation and seasonality. **Comments** It is unlikely that additional sampling will be able to detect differences in revegetated vs untreated areas of the drawdown zone, and this is reflected in Recommendations made in this report.
	e. Did revegetation affect bat utilization of habitat as measured by relative activity levels and estimated species richness recorded by remote acoustic detectors, based on: comparisons between revegetated and untreated areas, and/or vegetation change over the course of the monitoring study?	**Summary of Findings** We recorded 12 species of bat occurring in mid- and lower Arrow Lakes Reservoir. Lower Inonoaklin had the greatest number of bat recordings per detector-hour, followed by Edgewood South. We cannot comment on how revegetation affects bat utilization of habitat due to the inappropriate spatial scale of treatments within each site and lack of baseline bat data. **Sources of Uncertainty/Limitations** • The mobility of bats and limited spatial scale of revegetation treatments prevents the use of autonomous detectors for testing differences in treatment and control areas. • Lack of baseline sampling. **Comments** Habitat use by bats can be generalized to the study site only, as the wide-ranging aerial foraging precludes testing explicitly for revegetation effects based on the limited spatial extent of revegetation application.
	f. Did revegetation affect terrestrial arthropod abundance (e.g., biomass, catch per unit effort, etc.) and species richness, based on: comparisons between revegetated and untreated areas, and/or vegetation change over the course of the monitoring study?	**Summary of Findings** Results of 2018 arthropod biomass, abundance, richness, and diversity are consistent with those found in previous years. That is, no clear or consistent trends were found between these response measures and the revegetation treatments. Revegetation largely had no consistent effect on arthropod biomass, arthropod catch per unit effort (CPUE), Coleoptera family richness and diversity, Araneae species richness and diversity, or Carabidae species richness. An exception to this was that ground beetle diversity appeared to be greater in graminoid revegetation treatments at multiple sites, and ground beetle CPUE was greater in some (but not all) revegetation polygons at several sites relative to controls. Spider and ground beetle species composition was influenced by the interaction of study site and revegetation treatment, with similar species assemblages found in stake and graminoid treatments. Compositional differences between control and treatment polygons were pronounced when presence-absence data were analysed. Species assemblages were not found to be associated with per cent cover of LOM or substrate qualities recorded for each sampling location. **Sources of Uncertainty/Limitations**

Management Question (MQ)		Summary of Key Results
		• Low sample size for aerial arthropods (e.g., Hymenoptera and Diptera), due to constraints with Malaise tents. • Strong effect of site and other extraneous variables. • High reservoir levels precluding sampling of most revegetation polygons at each site. • Variation within treatment methods for revegetation treatments (species mixes, densities, fertilizer, method of planting, area selected for treating, etc.) impedes experimental design for hypothesis testing. • Lack of appropriate baseline data. • Natural annual population variation and seasonality. **<u>Comments</u>**
	g. Did revegetation affect ungulate utilization of habitat as measured by indices of use (e.g. pellet counts, tracks and occupancy), based on: comparisons between revegetated and untreated areas, and/or vegetation change over the course of the monitoring study?	**<u>Summary of Findings</u>** In 2018, we found evidence of ungulate use of seven sites, ranging from McKay Creek to Edgewood North. Majority of observations documented deer species, except for single observations of Elk and Moose signs. Ungulate aerial surveys conducted in 2010 and 2011 also concluded that ungulate use of the drawdown zone was not related to revegetation treatments. Ungulate pellet plots conducted from 2011 to 2014 provided little insight due to low pellet deposition in the drawdown zone. **<u>Sources of Uncertainty/Limitations</u>** • Incidental data only. • Type of observation (scat, tracks) limits species identification. • Home range of ungulate species much broader than scale of revegetation treatments. • Natural annual population variation and seasonality. **<u>Comments</u>** Ungulates appear to use the drawdown zone of Arrow Lakes Reservoir at all sites, regardless of revegetated area. None of the CLBWORKS-2 or CLBWORKS-30 prescriptions were developed with the objective of enhancing ungulate habitat. Rationale for discontinuing ungulate surveys as part of CLBMON-11B1, including issues of sample size, were previously discussed in Adama and Hawkes (2015). While shrub or stake plantings have the potential to provide cover and browsing opportunities for ungulates, results of revegetation monitoring suggest that there are few structural differences between these treatment areas and the adjacent drawdown zone habitat.
MQ2. Were the wildlife physical works projects effective at increasing wildlife utilization or enhancing the suitability of wildlife habitat to	**a.** How did the wildlife physical works projects affect the productivity of aquatic or terrestrial wildlife habitat in the treated drawdown zone sites?	**<u>Summary of Findings</u>** The Burton Creek wildlife physical works (WPW) site is currently (pre-treatment) a relatively unproductive field dominated by invasive reed canarygrass (Hawkes and Tuttle 2016). Two seasons of pre-treatment sampling has been conducted to serve as a baseline for future monitoring. Terrestrial and aerial arthropod biomass samples have been collected to compare with post-treatment arthropod biomass (as a proxy for productivity). **<u>Sources of Uncertainty/Limitations</u>** • Physical works have not been implemented. • Natural annual population variation.

<table>
<tr><th colspan="2">Management Question (MQ)</th><th>Summary of Key Results</th></tr>
<tr><td rowspan="3">a biologically meaningful extent?</td><td></td><td>

Short schedule for monitoring post-treatment response (monitoring should occur long enough after treatments have been implemented to allow for wildlife to colonize and establish in the newly created habitat).
Not currently monitoring wetland macroinvertebrates (e.g., Odonata), which are likely to respond to the WPW.
Variable reservoir operations.

<u>Comments</u>
Creation of shallow wetland habitat is likely to increase habitat heterogeneity with commensurate increases to species richness and improve both aquatic and terrestrial productivity.
</td></tr>
<tr><td>b. What were the baseline conditions at the wildlife physical works study sites in terms of aquatic and terrestrial wildlife habitat productivity and habitat quality?</td><td>
<u>Summary of Findings</u>
Pre-treatment habitat quality is relatively low for species such as arthropods, amphibians, songbirds, and waterfowl. This site is a homogenous grass field. We identified 26 families of Hymenoptera, 30 families of Diptera, seven families and 18 species of Araneae, 11 families of Coleoptera, and 12 species of Carabidae. This site had a notably high abundance of introduced species (Trochosa ruricola, Pterostichus melanarius, Carabus granulatus, and Clivina fossor). Amphibian surveys conducted in the vicinity of Burton Creek (near Burton Flats) show that pond breeding amphibians are using existing habitats nearby.
<u>Sources of Uncertainty/Limitations</u>

Physical works have not been implemented.
Natural annual population variation and seasonality
Short schedule for monitoring post-treatment response (monitoring should occur long enough after treatments have been implemented to allow for wildlife to colonize and establish in the newly created habitat).
Variable reservoir operations

<u>Comments</u>
Creation of a shallow water wetland at this site would likely improve habitat quality and habitat heterogeneity to the potential benefit of many different species. While introduced species of arthropods may not be excluded after habitat creation, their dominance may diminish as a more diverse community of native species is supported.
</td></tr>
<tr><td>c. How did wildlife physical works projects change the area (m^2) or increase the suitability of habitat for wildlife?</td><td>
<u>Summary of Findings</u>
Physical works at Burton Creek is expected to create ~2.8 ha of shallow wetland habitat.
<u>Sources of Uncertainty/Limitations</u>

Physical works have not been implemented.
Natural annual population variation.
Short schedule for monitoring post-treatment response (monitoring should occur long enough after treatments have been implemented to allow for wildlife to colonize and establish in the newly created habitat).
Variable reservoir operations.

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Provided we are given sufficient timelines for detecting habitat changes and wildlife establishment, future post-treatment monitoring will detail wildlife habitat and utilization of physical works projects.</td></tr>
<tr><td></td><td>d. Did wildlife physical works projects change the utilization of the drawdown zone by birds as a measured by species richness, abundance and nest productivity?</td><td><u>Summary of Findings</u>
Songbird species using the WPW area pre-wetland construction are few, and abundances low. In addition to songbirds, there is limited use of the WPW area currently by waterfowl – mostly limited to periods of high reservoir levels. Bird (notably waterfowl) richness and abundance appear to increase through the summer, peaking during the fall, based on two years of baseline monitoring. We expect that the WPW, once complete, will increase the utilization of that area by waterfowl and wetland-associated songbirds relative to baseline conditions.
<u>Sources of Uncertainty/Limitations</u>
• Physical works have not been implemented.
• Natural annual population variation.
• Short schedule for monitoring post-treatment response (monitoring should occur long enough after treatments have been implemented to allow for wildlife to colonize and establish in the newly created habitat).
• Variable reservoir operations.
<u>Comments</u>
Pre-construction baseline data should be expanded to more finely resolve seasonal usage of the Burton Creek area by waterfowl and other bird species; current usage of the WPW site by birds is low.</td></tr>
<tr><td></td><td>e. Did wildlife physical works projects change the utilization of the drawdown zone by bats as measured by relative activity levels and estimated species richness recorded by remote acoustic detectors?</td><td><u>Summary of Findings</u>
Two seasons of baseline data have been collected on bat activity and species at the Burton Creek WPW site. We found bat activity was consistently lower at Burton Creek relative to bat activity documented at other sites in the drawdown zone of Arrow Lakes Reservoir. In both years of pre-treatment monitoring, 11 species of bats were classified at this site.
<u>Sources of Uncertainty/Limitations</u>
• Physical works have not been implemented.
• Short schedule for monitoring post-treatment response (monitoring should occur long enough after treatments have been implemented to allow for wildlife to colonize and establish in the newly created habitat).
• Variable reservoir operations.
<u>Comments</u>
Pre-treatment data on bat species richness and activity levels will be compared to post-treatment monitoring data in a Before-After design to assess the effects of wildlife physical works.</td></tr>
</table>

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<tr><th colspan="2">Management Question (MQ)</th><th>Summary of Key Results</th></tr>
<tr><td></td><td>f. Did wildlife physical works projects change the abundance (e.g., biomass, catch per unit effort, etc.) and species richness of arthropods in the drawdown zone?</td><td><u>Summary of Findings</u>

Two seasons of baseline data have been collected on terrestrial arthropods at the Burton Creek WPW site using both pitfall traps (for sampling ground-dwelling species) and malaise traps (for sampling aerial insects). Thus, we have pre-treatment levels of biomass, relative abundance, richness, and diversity. In addition, we have collected species data for spiders and ground beetles at this site. Ground beetle communities appeared to be dominated by introduced species at this site.

<u>Sources of Uncertainty/Limitations</u>

• Physical works have not been implemented.
• Natural annual population variation.
• Short schedule for monitoring post-treatment response (monitoring should occur long enough after treatments have been implemented to allow for wildlife to colonize and establish in the newly created habitat).
• Not currently monitoring wetland macroinvertebrates (e.g., Odonata), which are likely to respond to the WPW.
• Variable reservoir operations.

<u>Comments</u>

Pre-treatment data on arthropod species richness, biomass, relative abundance, and composition will be compared to post-treatment monitoring data in a Before-After design to assess the effects of wildlife physical works. Additional monitoring of odonates would be beneficial to track anticipated changes in this group as wetland communities become established post-treatment.</td></tr>
<tr><td colspan="2">MQ3. Did the revegetation methods result in changes to wildlife habitat for songbirds or bats as measured by indices of habitat suitability and site productivity (e.g., arthropod biomass, catch per unit effort, etc.), based on comparisons between revegetated and untreated areas, and of revegetated areas over the course of the monitoring study?</td><td><u>Summary of Findings</u>

Revegetation did not result in changes to site productivity as measured by arthropod biomass or catch per unit effort (see Management Question 1a and 1f). While we cannot comment on prescribed treatment and control plot utilization by bats (due to reasons explained in MQ-1e), there is no strong evidence that revegetation methods resulted in overall changes to songbird habitat, except the cottonwood stake treatment at Lower Inonoaklin which appears to provide nesting habitat for shrub-nesting species.

<u>Sources of Uncertainty/Limitations</u>

• Variable reservoir operations.
• Variation within planting methods for stake and graminoid treatments.
• Lack of appropriate baseline data.
• Natural annual population variation and seasonality.

<u>Comments</u>

The lack of measurable differences between vegetation cover in treatment and control areas may explain why differences in arthropod biomass have not been found. In addition, there was a notion that treatments were applied in relatively poor areas of the drawdown zone, which may diminish any effect of revegetation when compared to adjacent control plots that were of better condition prior to implementation. Comparisons between treatment and control areas for bats or songbirds is problematic due to the small spatial scale of revegetation polygons which did not consider the average territory or foraging ranges for these focal taxa.</td></tr>
</table>

Management Question (MQ)	Summary of Key Results
MQ4. Did the methods used for wildlife physical works result in changes to wildlife habitat for songbirds and bats as measured by indices of habitat suitability and site productivity (e.g. arthropod biomass)?	**<u>Summary of Findings</u>** Two seasons of baseline data have been collected on terrestrial arthropods at the Burton Creek WPW site using both pitfall traps (for sampling ground-dwelling species) and malaise traps (for sampling aerial insects). Thus, we have pre-treatment levels of biomass, relative abundance, richness, and diversity. In addition, we have collected species data for spiders and ground beetles at this site. Ground beetle communities appeared to be dominated by introduced species at this site. **<u>Sources of Uncertainty/Limitations</u>** • Physical works have not been implemented. • Natural annual population variation. • Short schedule for monitoring post-treatment response (monitoring should occur long enough after treatments have been implemented to allow for wildlife to colonize and establish in the newly created habitat). • Not currently monitoring wetland macroinvertebrates (e.g., Odonata), which are likely to respond to the WPW. • Variable reservoir operations. **<u>Comments</u>** Pre-treatment data on arthropod species richness, biomass, relative abundance, and composition will be compared to post-treatment monitoring data in a Before-After design to assess the effects of wildlife physical works. Additional monitoring of odonates would be beneficial to track anticipated changes in this group as wetland communities become established post-treatment. Targeted surveys for amphibians and reptiles at the physical works location would enable the development of a pre-construction baseline against which future comparisons can be made.
MQ5. Which revegetation or wildlife physical works methods or techniques (including methods or techniques not yet implemented) are likely to be most effective at enhancing or protecting the productivity of wildlife habitat in the drawdown zone?	**<u>Summary of Findings</u>** Revegetation efforts appear to be largely ineffective at enhancing wildlife habitat in the drawdown zone. While birds and arthropods use revegetated areas, they also use control areas similarly. In addition, we were unable to detect meaningful differences between revegetation treatment types. Apart from a few observations of bird nests in Black Cottonwood stakes, we fail to find any evidence of habitat enhancement. The WPW project at Burton Creek is more likely to be effective as the design of the project considered the habitat requirements of multiple species that are likely to benefit from the project (e.g., waterfowl, amphibians, bats, aquatic macroinvertebrates). Pre-treatment sampling is being conducted at the Burton Creek WPW site, which will allow for detection of treatment effects. **<u>Sources of Uncertainty/Limitations</u>** • Lack of appropriate baseline (sampling did not occur prior to the application of the revegetation prescriptions). • Natural annual population variation and seasonality. • Lack of replication. • Mixed success of revegetation program. • Variable reservoir operations. • Physical works have not been implemented.

Management Question (MQ)	Summary of Key Results
	<u>Comments</u> Given the relatively low productivity of the Burton Creek WPW site, shallow wetland creation has the potential to effectively enhance habitat at that site. Given an appropriate duration for post-treatment monitoring, we anticipate increased bat activity, arthropod biomass, and utilization by waterfowl, amphibians, and aquatic macroinvertebrates.

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

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ACRONYMS AND DEFINITIONS

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

CPUE: Catch per unit effort. Refers to the number of individuals caught per trap, standardized to a 24-hour trapping period.

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

Habitat Type: Within each site, sampling was conducted in control and treatment polygons, collectively referred to as habitat types. The habitat types are defined as follows:

> **Control:** area of the drawdown zone that was not revegetated using the revegetation prescriptions developed for CLBWORKS-2. Controls were placed in areas of similar elevation, topography, and substrate as treatment polygons, to serve as untreated paired controls within the study sites that were revegetated.
>
> **Treatment:** area of the drawdown zone that was revegetated using one of the revegetation prescriptions developed for CLBWORKS-2. Wildlife effectiveness monitoring focused on areas that received live stake revegetation treatment and graminoid (plug seedling) treatment.
>
> **Drawdown Zone:** a general term referring to the area ≤ 440.1 m ASL in a study site which is influenced by reservoir inundation. The drawdown zone encompasses both control and revegetation treatment polygons and/or proposed Wildlife Physical Works (WPW) locations.
>
> **Wildlife Physical Works (WPW):** To date no WPW projects have been implemented. Two have been designed (Lower Inonoaklin Road and Burton Creek wetlands), and one is planned (Burton Creek Wetlands). The physical works planned for Burton Creek include the creation of a series of tiered wetlands, mounding of soil to increase topographic heterogeneity, and a reed canarygrass (*Phalaris arundinacea)* removal trial.

LOM: Live organic matter (measured in per cent cover); serves as a proxy for vegetation cover.

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

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

> **Stake**: includes excavator-planted (EPL) and hand-planted (HPL) live black cottonwood stakes.
>
> **Graminoid**: sedge plug seedlings.

Study Site: refers to a broad geographic area of the reservoir used as the highest level of stratification for sampling. The wildlife effectiveness monitoring areas corresponded with select revegetation treatment areas and are shown in Figure 3-1.

1.0 INTRODUCTION

The Columbia River Water Use Plan was developed as a result of a multi-stakeholder consultative process to determine how to best operate BC Hydro's Mica, Revelstoke, and Keenleyside facilities to balance environmental values, recreation, power generation, culture/heritage, navigation, and flood control. The goal of the Water Use Plan is to accommodate these values through operational means (i.e., patterns of water storage and release) and non-operational physical works in lieu of changing reservoir operations to address specific interests.

During the Water Use Planning process, the Consultative Committee supported the following projects to enhance wildlife habitat in the Arrow Lakes Reservoir, in lieu of maintaining lower reservoir levels:

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

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

This report outlines monitoring and results of CLBMON-11B1 in 2018[1], which focus on revegetation treatments (CLBWORKS-2) and wildlife physical works baseline conditions under CLBWORKS-30B.

2.0 OBJECTIVES AND MANAGEMENT QUESTIONS

CLBMON-11B1 is the first module in a suite of related effectiveness monitoring studies in the Arrow Lakes Reservoir, all of which were developed under one common CLBMON-11B Terms of Reference (TOR) in 2009. The Terms of Reference for CLBMON-11B projects was revised in 2017. This report follows the questions and structure of the revised TOR (BC Hydro 2017). Refer to the revised TOR (BC Hydro 2017) for Objectives and Management Questions of all CLBMON-11B modules. The objectives of the CLBMON-11B1 program, as defined in the 2017 Terms of Reference, are as follows:

1. Assess the effectiveness of the revegetation program (CLBWORKS-2) with respect to wildlife use of the drawdown zone of the Arrow Lakes Reservoir.

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

2. Assess the effectiveness of the wildlife physical works projects (CLBWORKS-30A, CLBWORKS-30B) at improving and/or sustaining conditions for nesting and migratory birds and wildlife in the drawdown zone of Arrow Lakes Reservoir.
3. Provide recommendations on revegetation or wildlife physical works methods or techniques most likely to be effective at enhancing or protecting the productivity of wildlife habitat in the drawdown zone of the Upper and Lower Arrow Lakes Reservoir.
4. Monitor specific areas identified under CLBWORKS-29B as providing high value wildlife habitat to determine opportunities for protection and enhancement within the Arrow Lakes Reservoir.

2.1 Management Questions

The Management Questions included in the CLBMON-11B1 program, as defined in the 2017 Terms of Reference, are as follows:

1. Were the revegetation projects effective at increasing wildlife utilization or enhancing the suitability of wildlife habitat to a biologically meaningful extent?
    a. How did the revegetation projects affect the productivity (measures of biomass, or reproductive success) of wildlife habitat in the drawdown zone?
    b. What were the conditions at the revegetation study sites in terms of wildlife habitat suitability at the time of project initiation?
    c. How did revegetation modify the area (m^2) or the suitability of wildlife habitat based on: comparisons between treated and untreated areas, vegetation change over the course of the monitoring study, and available baseline data on vegetation structure?
    d. Did revegetation affect songbird utilization of habitat as measured by species richness and/or relative abundance, based on: comparisons between revegetated and untreated areas, and/or vegetation change over the course of the monitoring study?
    e. Did revegetation affect bat utilization of habitat as measured by relative activity levels and estimated species richness recorded by remote acoustic detectors, based on: comparisons between revegetated and untreated areas, and/or vegetation change over the course of the monitoring study?
    f. Did revegetation affect terrestrial arthropod abundance (e.g., biomass, catch per unit effort, etc.) and species richness, based on: comparisons between revegetated and untreated areas, and/or vegetation change over the course of the monitoring study?
    g. Did revegetation affect ungulate utilization of habitat as measured by indices of use (e.g. pellet counts, tracks and occupancy), based on: comparisons between revegetated and untreated areas, and/or vegetation change over the course of the monitoring study?

2. Were the wildlife physical works projects effective at increasing wildlife utilization or enhancing the suitability of wildlife habitat to a biologically meaningful extent?
    a. How did the wildlife physical works projects affect the productivity of aquatic or terrestrial wildlife habitat in the treated drawdown zone sites?
    b. What were the baseline conditions at the wildlife physical works study sites in terms of aquatic and terrestrial wildlife habitat productivity and habitat quality?
    c. How did wildlife physical works projects change the area (m^2) or increase the suitability of habitat for wildlife?
    d. Did wildlife physical works projects change the utilization of the drawdown zone by birds as a measured by species richness, abundance and nest productivity?
    e. Did wildlife physical works projects change the utilization of the drawdown zone by bats as measured by relative activity levels and estimated species richness recorded by remote acoustic detectors?
    f. Did wildlife physical works projects change the abundance (e.g., biomass, catch per unit effort, etc.) and species richness of arthropods in the drawdown zone?
3. Did the revegetation methods result in changes to wildlife habitat for songbirds or bats as measured by indices of habitat suitability and site productivity (e.g., arthropod biomass, catch per unit effort, etc.), based on comparisons between revegetated and untreated areas, and of revegetated areas over the course of the monitoring study?
4. Did the methods used for wildlife physical works result in changes to wildlife habitat for songbirds and bats as measured by indices of habitat suitability and site productivity (e.g. arthropod biomass)?
5. Which revegetation or wildlife physical works methods or techniques (including methods or techniques not yet implemented) are likely to be most effective at enhancing or protecting the productivity of wildlife habitat in the drawdown zone?

2.2 Key Water Use Decisions Affected

The Terms of Reference for CLBMON-11B1 indicate that the results of this study will aid in more informed decision-making with respect to the need to balance the requirements of wildlife that are dependent on wetland and riparian habitats with other values such as recreational opportunities, flood control and power generation.

The key water use planning decisions affected by the results of this monitoring program are whether revegetation and wildlife physical works are effective in enhancing wildlife habitat. Results from this study will also assist in refining the approaches and methods for enhancing wildlife habitat through adaptive management.

3.0 STUDY AREA

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

Sites were selected based on areas treated under CLBWORKS-2 (Keefer et al. 2009) that had evidence of revegetation success (Miller et al. 2018). Starting in 2017, sampling also occurred at sites where potential wildlife enhancement projects were being considered for development under CLBWORKS-30B and at select revegetation areas in Revelstoke Reach.

The proposed wildlife physical works (WPW) location, Burton Creek, is located south of Nakusp, on the east side of Arrow Lakes Reservoir. The site is currently a depression with low species diversity, dominated by non-native reed canarygrass. The site is currently unsuitable for waterfowl, aquatic invertebrates, and aquatic macrophytes. Some songbirds (likely originating from the adjacent wooded areas), amphibians, and reptiles have been documented from this area. The proposed project would create approximately 2.8 ha of shallow wetland habitat.

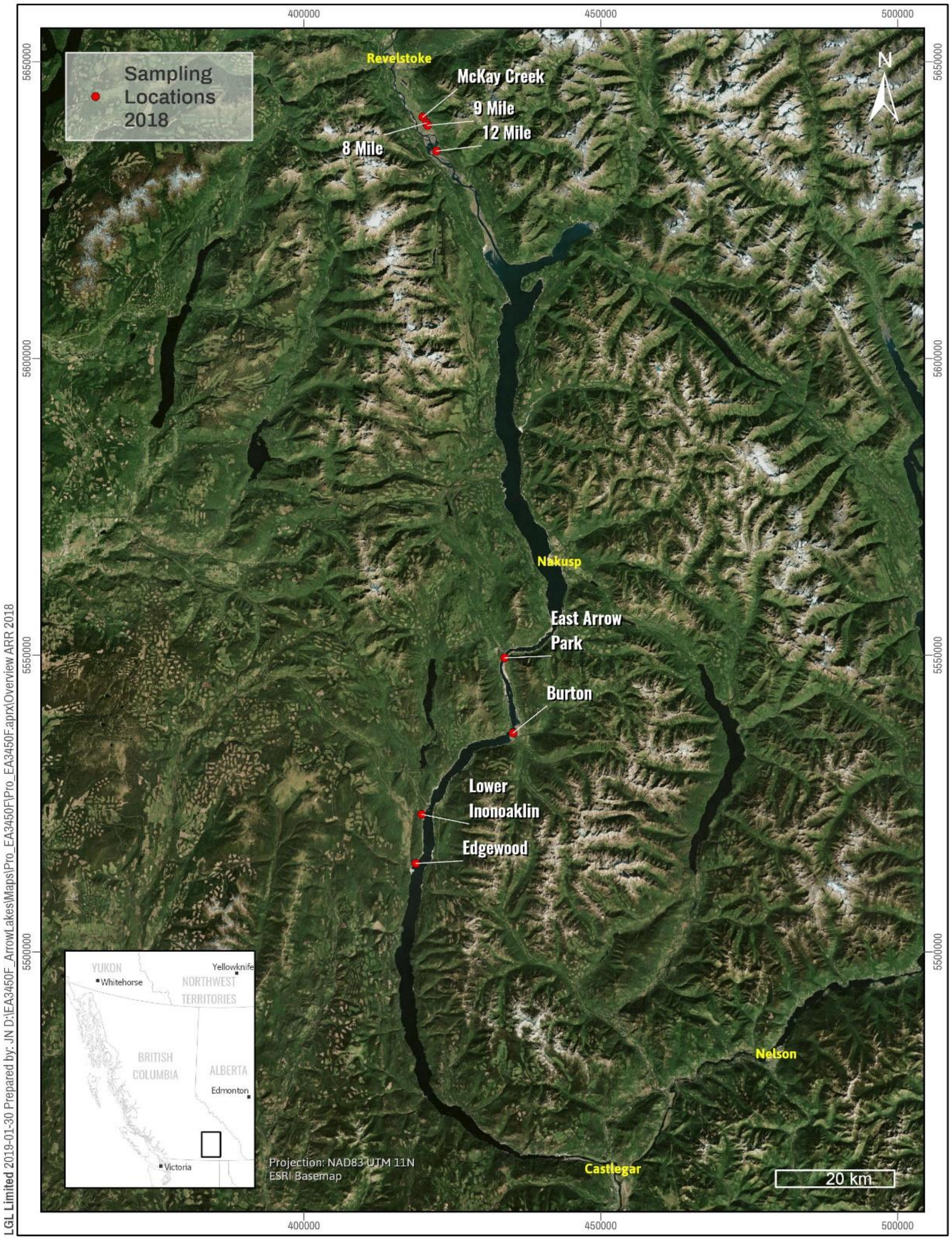

Figure 3-1: Location of 2018 wildlife monitoring sites within Arrow Lakes Reservoir in B.C. Note: only birds were surveyed at McKay Creek, 8 Mile, and East Arrow Park. Arthropods and birds were sampled at all other sites. See Appendix E for locations of bat detectors, which included monitoring in a non-reservoir location at Armstrong Lake.

4.0 METHODS

4.1 Revegetation Treatments (CLBWORKS-2)

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

We summarized revegetation prescriptions and surviving vegetation densities by site for the target treatment polygons sampled under CLBMON-11B1 in 2018, utilising information provided by Miller et al. (2018) and Hawkes et al. (2018). This included the initial planting densities and 2017 vegetation densities for two broad revegetation types that were found to have had some revegetation success (Miller et al. 2018): graminoid seedling and shrub stakes. Definitions are as follows:

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

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

4.2 Wildlife Physical Works (CLBWORKS-30B)

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

The proposed Burton Creek physical works location is adjacent to Highway 6 from which it is highly visible, and accessible via Robazzo Road (Figure 4-1). The environmental objectives for the physical works are found in KWL (2018) and repeated here. The purpose of this project is to create shallow wetland habitat for Western Toad (assessed as a species of Special Concern by the Committee on the Status of Endangered Species in Canada; COSEWIC 2012), nesting and migratory birds, and other wildlife by excavation of pools and construction of water retention berms or similar to meet the terms of the Columbia Order. The goal is to retain site drainage and groundwater to promote stability of the wetland habitat. As discussed in the 2016 Feasibility Study, the objectives of the proposed wildlife physical works are to:

- Increase the spatial and temporal availability of shallow wetland habitat for wildlife in the drawdown zone of Arrow Lakes Reservoir within the habitat window of interest of April 1 to October 31.
- Improve habitat complexity in the drawdown zone of Arrow Lakes Reservoir.
- Improve wildlife habitat suitability by creating habitat that will benefit several groups of wildlife including migratory birds, nesting birds, pond-breeding amphibians, reptiles, bats, insects, and mammals.
- Reduce the cover of Reed Canary Grass (RCG) in the drawdown zone to promote the growth of native plants through terrestrial revegetation program that will follow the completion of the physical works.
- Revegetate the new wetland habitat with native aquatic macrophytes and riparian vegetation.

To ensure that the design satisfies environmental needs, LGL and BC Hydro were consulted to provide the environmental requirements and constraints for the design, as listed below:

- Create successful wetland habitat incorporating shallow and deep configurations with submerged and floating macrophytes, considering a phased approach with various add-on features. The 2016 Feasibility Study proposed approximately 2.8 ha of shallow wetland habitat, with a minimum area of 2.0 ha. However, the project team agreed that there is no specific minimum area target, and that the main goal is to ensure the creation of successful habitat. As such, the feasible wetland area will be determined considering the hydrology/hydrogeology assessment, and phasing will be incorporated to initially test success at a smaller scale.
- Target water depth in the majority of the wetlands with an average depth of between 0.3 and 0.5 m for shallow wetland habitat, with some limited areas that could be slightly deeper. The feasibility study proposed depths of 0 to 1.5 m; however, target depths have been decreased to limit the suitability and attractiveness for Canada Geese in the shallow pond habitat. Deeper wetland features for waterfowl are under consideration (potentially as a later phase) with depths in the range of 1 to 1.2 m, with shallow fringes.
- Retain water from runoff and shallow groundwater from Burton Creek along the eastern side of the proposed site.
- Create wetlands with and without connectivity to each other to allow comparative study on the effectiveness of these types of configurations and connectivity. It is expected that outlet structures and disconnected wetlands will pose a barrier to fish or other species returning to the reservoir, which may result in stranding due to decreasing water levels. Disconnected wetlands could be connected if monitoring results indicate connected wetlands perform better; however, it is expected that fish stranding will be an ongoing risk (an assessment has not been conducted to confirm that). The existing gravel pits at the north end of Burton Flats currently pose a risk for fish stranding, and the design concepts could incorporate reconnecting these ponds to the reservoir. It was noted that fish stranding would benefit some target wildlife.
- Include planting with native sedges and possibly cottonwood, willow or other tree species in the design. Where possible, the plants should align to culturally important native species.
- Create habitat mounds with the top of the mounds at a minimum elevation of 439 m, planted with inundation-tolerant shrubs. Planting of nesting shrubs should have a minimum elevation of 439 m.

- Incorporate naturalized elements and bio-technical approaches in the design for both habitat complexity and aesthetics (to promote local stakeholder support), such as ‘soft engineering’ solutions on the wetland side of the berms, large woody debris with root wads in select locations, riffle and pool sequences, and gentle edges or other variations to berm geometry (height, width, alignment and cross section). Consider variation from pond to pond for diverse habitats.
- Incorporate trial RCG suppression techniques with varied planting approaches and species to enhance continued learning regarding planting within and adjacent to the drawdown zone of reservoirs, and specifically the Arrow Lakes system (See Vegetation sub-section of Section 2.3 - Wetland Design).

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

In general, the proposed physical works incorporates elements of shallow tiered wetlands, secondary, stand-alone wetlands, deep ponds, planting mounds with varying crest elevations, and a reed canargygrass exclusion trial (Figure 4-1).

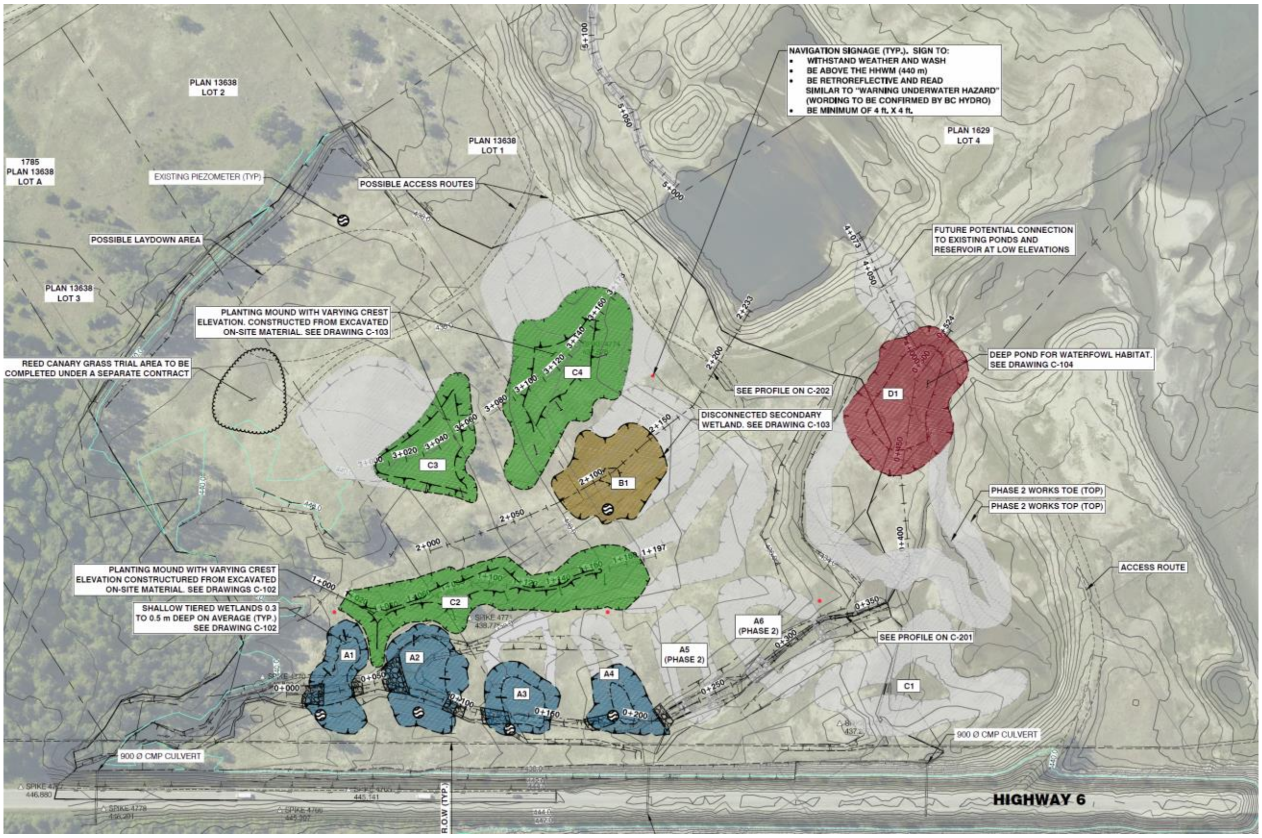

Figure 4-1: **Schematic of the proposed physical works at Burton.** The proposed physical works incorporates elements of shallow tiered wetlands (blue polygons, secondary, stand-alone wetlands (brown), deep ponds (red), planting mounds with varying crest elevations (green), and a reed canarygrass exclusion trial (dashed polygon). Schematic from KWL (2018) .

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

4.3 Experimental Design

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

4.3.1 Revegetation monitoring design

To align wildlife sampling with CLBWORKS-2 revegetation prescriptions and CLBMON-12 revegetation effectiveness monitoring, we obtained shapefiles of the 2008-2011 treatment polygons from Keefer Ecological Services. Because we wanted to compare treated areas to non-treated (or control) areas, we used the following approach to identity control and treatment polygons in each site where revegetation prescriptions were applied:

1. Using ArcMap 10, we selected the treatment polygons of interest (successful[2] graminoid or stake treatments as identified by Miller et al. 2018).
2. Sampling locations for arthropods and birds were selected within treatment polygons, accounting for appropriate spacing between sampling locations (e.g., 30 m radius around point count stations thus >60 m between point count stations; 10 m minimum distance between pitfall traps).
3. Control locations were selected at similar elevations and in proximity to treatment polygons, where possible.
4. The number of songbird sampling station cells selected per treatment or control polygon was a function of polygon size. Where possible, a minimum of two songbird point count stations were selected within each control and treatment polygon. Three pitfall trapping locations and one malaise trap location were selected within each control and treatment polygon.

4.3.2 Wildlife Physical Works Monitoring Design

The efficacy of the physical works proposed for Burton Creek will be assessed using a Before-After assessment. The data collected to date represent the before period with data collection occurring in the physical works locations related to arthropods, birds (songbirds and waterfowl), bats, amphibian and reptiles (with before data obtained from CLBMON-37 and targeted sampling in 2019), and vegetation. Large mammal use (e.g., ungulates) of the physical works location is based on opportunistic observations of wildlife and associated sign. Wildlife monitoring of the groups of wildlife will continue following completion of the physical works.

Data collection methods at the physical works location were the same as those used to assess the effectiveness of revegetation treatments to provide habitat for wildlife. In addition to sampling for arthropods, songbirds and bird nests, and bats, data were collected on the occurrence and distribution of waterfowl. Data on the distribution and occurrence of waterfowl were recorded from Burton Creek. Sampling occurred approximately weekly throughout the months of May, August and September 2018. The occurrence of all bird species using Burton Creek in the spring, summer and fall were mapped to provide an indication of the use of the area by birds during the fall migration period.

4.4 Response Measures

An effectiveness monitoring program should be designed to determine how well management activities, decisions, or practices meet the stated objectives of the program (Marcot 1998, Noon 2003). Key to designing an effectiveness monitoring program is the selection of sensitive and readily measurable response variables that are appropriate to the objectives of the management action (Machmer and Steeger 2002); however, the selection of indicators (e.g., focal species) can be challenging (Andersen 1999). The selection of indicator species/processes should be guided by their sensitivity to the management practice, the ease of collecting data, and the usefulness of the information to address the management activity

[2] Success was herein defined as any revegetation polygon having at least one surviving transplant.

(Chase and Guepel 2005). Potential indicators may include habitat attributes, keystone species, species at risk, species that are sensitive to specific habitat requirements, or species that can be monitored easily (Feinsinger 2001, Chase and Guepel 2005). The selection of indicators should also be appropriate to the spatial scale of the applied management activity and must take into consideration factors that are external to the monitoring program, such as inter- and intra-specific competition, predation, climatic change, disease, time of year, and in the case of CLBMON-11B1, normal reservoir operations.

4.4.1 Terrestrial Arthropods

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

In addition to being an important food source for many vertebrate taxa, such as birds, amphibians, and small mammals, terrestrial arthropods are integral to ecosystem processes such as decomposition, pollination, nutrient cycling, predation, and parasitism. Terrestrial arthropod abundance and diversity could be expected to increase with increasing vegetation structure and diversity (e.g., Humphrey et al. 1999; Söderström et al. 2001). Because of the trophic linkage between vegetation, arthropods, and songbirds, the inclusion of terrestrial arthropods as a focal species group to monitor makes intuitive sense. In addition, the relatively small spatial scale of revegetation polygons (min= 0.0024, mean= 0.62 ha, max= 7.4 ha) is better suited to arthropod monitoring than wildlife with larger ranges.

Arthropod Sampling

Terrestrial arthropods were sampled at six main study sites in 2018: 9 Mile, 12 Mile, Burton Creek, Lower Inonoaklin, Edgewood North and Edgewood South (-Appendix A). This included sampling of eight treatment polygons, one Wildlife Physical Works location, and six control polygons (untreated drawdown zone locations). The polygons that were sampled for arthropods are detailed in Appendix B. The type of revegetation polygons consisted of five stake treatments and three graminoid treatments.

Consistent with previous years (e.g., Hawkes et al. 2011, 2014, 2018; Sharkey et al. 2018; Wood et al. 2018), arthropods were sampled via two trapping methods: pitfall trap arrays and Malaise traps. One Malaise trap was installed within a control and treatment polygon at each site (where possible, see Appendix B). In addition, three pitfall array units were established per polygon in the drawdown zone. While monitoring was intended to occur in a greater number of treatment polygons per study site, this was not possible due to the high reservoir elevations during the

2018 arthropod sampling periods. Thus, the number of samples at a given site varied based on the availability of polygons.

Given the short temporal duration of our sampling and limited area of polygons, we chose a 10 m minimum spacing for randomly selecting array unit locations within each polygon. This inter-trap spacing distance for analyzing patterns of abundance, richness, and composition, aligns with that of Samu and Lövei (1995) and Bess et al. (2002). Some authors found a lesser spacing distance appropriate for these studies [5 m (Ward et al. 2001) and 7.5 m (Bellocq et al. 2001)]. Over longer collection periods, it would be beneficial to space pitfall trap replicates at least 25 m apart to avoid potential depletion of local taxa (Digweed et al. 1995). The limited spatial extent of revegetation polygons would not allow for pitfall trap spacing of that criteria.

Pitfall arrays were comprised of four traps (473 mL clear plastic Amcor® food cups) inserted into the ground, spaced 1 m apart at randomly determined sampling locations. Traps were filled with ~100 mL of preservation fluid (Propylene glycol, Univar Canada Ltd.) and checked daily to ensure functionality and record trap disturbance. Each pitfall trap was used to generate two sample types: a diversity sample (used for arthropod identification, relative abundance, relative richness, diversity, and composition) and a biomass sample (used to measure dry weight of arthropod sample contents). In each pitfall array, three traps were collected as a biomass sample and one trap was collected as a diversity sample for arthropod identification. Each Malaise trap generated one sample that was used for both biomass and diversity information.

To align with previous monitoring years and capture some temporal variation in arthropod abundance and composition, we intended to collect samples in two collection periods. In previous years collections were generally made in June and July, as abundance is generally lower in May (unpublished CLBMON-11B1 data from 2011 and 2013 monitoring). However, projected reservoir elevations during arthropod monitoring in 2017 and 2018 necessitated all sample collections be made during the month of June. Collection period one occurred between June 3rd and June 11th and collection period two occurred between June 21st to June 27th, with each trap operational for approximately 72 hours (exact dates for each trap are provided in Appendix C). Despite these efforts to expedite sampling, reservoir levels limited and prevented access to several of the sampling polygons during one or both collection periods (Figure 4-2). The 2018 monitoring season generated a total of 158 samples (Table 4-1).

Figure 4-2. Pictures of access road to 9 Mile on June 4 (top) and June 23 (bottom) during 2018 collections in the Arrow Lakes Reservoir.

Table 4-1. **Number of arthropod samples collected for CLBMON-11B1 in 2018.** BU= Burton, ES= Edgewood South, EN= Edgewood North, LI= Lower Inonoaklin, 9M=9 Mile, 12M=12 Mile. WPW=Wildlife Physical Works (pre-treatment sampling).

			Collection 1			Collection 2			
Site	Treatment	Revegetation Polygon	Malaise	Pitfall Biomass	Pitfall Diversity	Malaise	Pitfall Biomass	Pitfall Diversity	Total
BU	Graminoid	2009_64			3				**3**
	Control		1	3	3	1	2	2	**12**
	WPW		1	5	5	1	5	5	**22**
ES	Stake	2009_1		3	3				**6**
	Stake	2009_3	1	3	3				**7**
	Control		1	3	3				**7**
EN	Graminoid	2011_31	1	3	3				**7**
	Control		1	3	3				**7**
LI	Stake	2009_18	1	3	3		3	3	**13**
	Graminoid	2011_23		2	3				**5**
	Control		1	3	3		3	3	**13**
9M	Stake	2010_RR8	1	3	3	1	3	3	**14**
	Control		1	3	3	1	3	3	**14**
12M	Stake	2010_RR11_A	1	3	3	1	3	3	**14**
	Control		1	3	3	1	3	3	**14**
	Total		**12**	**43**	**47**	**6**	**25**	**25**	**158**

Sample Processing and Identification

With the aid of taxonomic specialists, arthropods from diversity pitfall trap samples were counted and classified to two taxonomic levels: 1) species for all spiders (Araneae) and ground beetles (Coleoptera: Carabidae), and 2) order for remaining taxa (Hymenoptera, Diptera, Orthoptera, etc.). Malaise trap sample contents were sorted and identified for families of Hymenoptera and Diptera. Following identification of these groups, these specimens were aggregated with the rest of the Malaise sample contents for processing as biomass.

Each biomass sample was weighed to the nearest centigram and placed in a drying oven. The samples were weighed each day during drying until the weight stabilized, indicating that drying was complete. On average, samples were dried for 76.3 hours (min= 47.0 hours, max= 150.8 hours). The final dry weight of each sample was then used in biomass calculations.

4.4.2 Birds

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

Point Count Surveys

Time-constrained, variable-radius[3] point count surveys were used to assess the diversity and relative abundance of songbirds (Ralph et al. 1995). In total, 76 point count stations were surveyed in 2018 at nine sites (Table 4-2, Appendix E). Each site was attempted to be visited twice through the survey period; however, due to higher reservoir water levels, fewer point count stations could be surveyed on the second visit (Table 4-2). Treatment point counts were distributed in different revegetation polygons (Appendix B), depending on size and availability of polygons at each site. In total there were 10 graminoid polygons and 18 stake polygons, cumulatively containing 19 and 33 surveyed point count stations respectively (Table 4-2).

Table 4-2. Number of point count stations surveyed in 2018 by site, and treatment type. Numbers in brackets refer to the number of revegetation polygons sampled (see also Appendix B). WPW = Wildlife Physical Works. Totals refer to the number of unique point count stations and polygons per site and treatment type.

Site	Treatment Type												Total		
	Control			Graminoid			Stake			WPW					
	Visit			Visit			Visit			Visit			Visit		
	1	2	Tot	1	2	Tot	1	2	Tot	1	2	Tot	1	2	Tot
8 Mile	4	0	4	0	0	0	6 (2)	5 (2)	6 (2)	0	0	0	10	5	*10*
9 Mile	3	0	3	0	0	0	3 (1)	2 (1)	3 (1)	0	0	0	6	2	*6*
12 Mile	2	1	2	1 (1)	0	1 (1)	6 (3)	3 (2)	6 (3)	0	0	0	9	4	*9*
McKay Creek	3	0	3	0	0	0	6 (6)	5 (5)	6 (6)	0	0	0	9	5	*9*
Burton Creek	1	1	1	1 (1)	0	1 (1)	3 (1)	2 (1)	3 (1)	5	2	5	10	5	*10*
East Arrow Park	1	0	1	7 (3)	0	7 (3)	0	0	0	0	0	0	8	0	*8*
Edgewood North	2	2	2	4 (2)	5 (3)	6 (3)	0	0	0	0	0	0	6	7	*8*
Edgewood South	2	2	2	0	0	0	4 (2)	2 (2)	4 (2)	0	0	0	6	4	*6*
Lower Inonoaklin	1	1	1	4 (2)	2 (1)	4 (2)	5 (3)	2 (1)	5 (3)	0	0	0	10	5	*10*
Total	*19*	*7*	*19*	*17 (9)*	*7 (4)*	*19 (10)*	*33 (18)*	*21 (14)*	*33 (18)*	*5*	*2*	*5*	*74*	*37*	*76*

The timing of the songbird surveys (03-30 June, 2018) coincided with the height of the breeding season at which time all locally breeding birds are on territory and are highly vocal, enabling surveyors to document the number and diversity of breeding birds. Surveys commenced at sunrise and ended within ~4 hours of sunrise (Ralph et al. 1995). Songbird surveys were done during favourable weather conditions only (i.e., no heavy wind or precipitation) to standardize surveys and minimize variable detections associated with sub-optimal environmental conditions. All songbird surveys conformed to the provincial standard (RIC 1999).

Point count surveys were conducted at Treatment (both stake and graminoid revegetation plots) and Control stations, as well as baseline stations within the

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

proposed WPW area at Burton Creek (Appendix B). Treatment stations occurred within previously revegetated polygons, and Control stations within non-revegetated areas of the drawdown zone in proximity to treatment areas (see also Appendix E).

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

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

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

Nest Searches

Nest searches were completed within the drawdown zone and immediately adjacent areas at all sites where point counts were conducted. Polygons were searched over the same date span as point count surveys, typically occurring after the point count period had ended for a given day. Nest searches were not limited by taxa, though focused on songbirds and shorebirds.

Waterbird Surveys

Surveys focused on waterbirds were completed on four dates from late April to late May, and nine dates from early August to late September. These waterbird surveys were conducted in the Burton Creek area, with the goal of providing baseline waterbird information relevant to the proposed physical works. Waterbird surveys were approximately 1 hour to 3.5 hours in duration. During each survey period a map showing the Burton Creek area and approximated water levels for that date was provided, and the number and species of birds (all birds, but with a focus on waterbirds) was recorded onto the map.

4.4.3 Bats

There are 12 bat species potentially occurring in the West Kootenays, most confirmed by live capture studies (excluding *Myotis ciliolabrum*). Five of these twelve species are of conservation concern at the provincial and/or national level

(Table 9-1). While bats are not appropriate focal taxa for detecting differences between polygons on the spatial scale of the CLBWORKS-2 revegetation program, we select bats for monitoring across the reservoir drawdown zone and non-drawdown zone habitats as these data are important documentation of species at risk utilizing Arrow Lakes Reservoir. In addition, these bat data may be useful for comparisons to the bat activity recorded in future years of monitoring at the Burton wildlife physical works site. Further reporting of general Arrow Lakes Reservoir bat data is provided in Appendix F.

4.4.4 Response Measures for Wildlife Physical Works Monitoring

The WPW has not yet been implemented. However, several performance measures have been proposed to assess success of the Burton Creek physical works (Hawkes and Tuttle 2016). In 2018 baseline conditions for arthropods, songbirds, and bats were investigated, conforming to methods described above for those groups. In addition, waterfowl presence and abundance was determined with separate surveys in April/May, August, and September, 2018. Currently the Wildlife Physical Works location is dominated by grasses, and no wetland habitat exists. Evidence of use and establishment of species from a variety of taxonomic groups (e.g., macroinvertebrates, amphibians, native macrophytes) will be studied once WPW construction has been implemented. The current (baseline) conditions of the pre-wetland area are monitored so that effective change for those groups can be quantified.

4.5 Live Organic Matter and Substrate Classification

We classified basic soil substrate conditions within each treatment and control polygon to assess the variation in conditions between sampling locations, which may relate to habitat use by arthropods. This was not a variable of interest specified by the TOR, but is useful to characterise differences in revegetation and control areas (see Table 5-1). We estimated per cent cover of live organic matter (LOM) and soil substrate classes within a 1 m^2 quadrat at each pitfall trap array location in each polygon. LOM served as a proxy for vegetation cover for each treatment polygon in the drawdown zone. Soil substrate included woody debris, moss, lichen, broad soil type (silt, sand, fines, or peat), and plant litter. In addition, canopy cover (per cent) was estimated at each sampling point. We measured LOM during the first collection at each pitfall trap array (n=3 per polygon) in revegetated stake (n=5), graminoid (n=3), and control (n=6) polygons. We also measured LOM at pitfall trap arrays (n=5) in the WPW site.

4.6 Data Analyses

In general, data analyses followed those performed in recent years (e.g., Hawkes et al. 2018b; Hawkes et al. 2014). Most of the results reported summarize the data collected in 2018 only. Analyses varied based on the management question and qualities of the resultant dataset and are discussed for each section below.

4.6.1 Revegetation Treatments

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

4.6.2 Terrestrial Arthropods

The total number of diversity and biomass samples from both trap types (Malaise and pitfall) are given in Table 4-1. All samples are from the 2018 monitoring year. To eliminate temporal pseudoreplication, we limited interpretation of results to the first sampling period. All arthropod boxplots therefore only present data from the first sampling period. For data that did not involve comparison (such as reporting arthropod families or species and associated abundances), all available data was used from both collection periods.

All analyses (where performed) were conducted in the R programming language (R Core Team 2018). P-values less than α=0.1 were considered significant. Diversity and compositional analyses were performed with the vegan package (Oksanen et al. 2018).

Relative abundance (CPUE)

Relative abundance was calculated as catch-per-unit-effort (CPUE), equal to the number of arthropods caught per pitfall trap sample, standardized to a 24-hour trapping period (i.e., arthropods per trap-day). This metric was generated from diversity samples only, as biomass samples were not sorted for measures of arthropod abundance. Relative abundance was also calculated for adult spiders (Araneae) and ground beetles (Carabidae) as the number of individuals in each group caught per trap, standardized to a 24-hour trapping period (CPUE, as above). Boxplot graphs were provided for mean CPUE of pitfall trap samples (n=3 pitfalls for each stake (n=5), graminoid (n=3), and control (n=6) polygon, in each site, from the first collection).

Richness

We standardized richness for trapping effort (per 24-hour trap day) for each pitfall trap (n=3 per polygon) at each stake (n=5), graminoid (n=3), and control (n=6) polygon from the first collection. Samples were rarefied to a sample size of two for comparison using the R package vegan (Oksanen et al. 2018). Boxplot graphs were provided for rarefied richness of three groups (Coleoptera families, Araneae species, and Carabidae species). For species richness comparisons, samples were limited to adult individuals identified to species (i.e., adult spiders and ground beetles).

Diversity

We assessed arthropod diversity using the Shannon-Wiener index, standardized by trapping effort (per 24-hour trap day) for each pitfall trap (n=3 per polygon) at each stake (n=5), graminoid (n=3), and control (n=6) polygon. Boxplot graphs were provided for diversity of three groups (Coleoptera families, Araneae species, and Carabidae species) from the first collection. For species diversity comparisons, samples were limited to adult individuals identified to species (i.e., adult spiders and ground beetles).

The limited sample size of Malaise traps (n=1) for each stake (n=4), graminoid (n-1), and control (n=6) polygon prevented in-depth diversity analysis. Instead, we employed a descriptive approach and presented the three families most common at each site based on proportion of catch for the first collection (in cases of a tie, we listed all families with similarly high proportions) and discussed family representation at the polygon and site level.

Biomass

Biomass was calculated as the dry weight of arthropods (mg) per trap-hour for each sample. This included samples from pitfall traps (n=3, except for n=2 at polygon 2011_23 in Lower Inonoaklin) from graminoid (n=2), stake (n=5), and control (n=6) polygons in the first collection period. Biomass pitfall trap results were presented via boxplot graphs. Malaise trap samples from the first collection period were considered uninformative due to data restrictions. (n=1 per treatment polygon for stake (n=4), graminoid (n=1), and control (n=6) polygons) and were removed from comparison.

Composition

Spider and beetle species composition were calculated from graminoid, stake, and control diversity pitfall trap samples. This included 62 of the total 72 diversity samples collected (Table 4-1; 10 samples collected at the WPW site were excluded). Pooling abundances from the two collection periods for each trap and excluding replicates that did not contain any spiders or beetles resulted in 34 replicates containing spiders and 36 replicates containing beetles for use in community analyses. Only species-level determinations of adult arthropods are included in analyses (28 spider species and 40 ground beetle species; see Appendix G).

Current approaches in community ecology focus less on species richness, and increasingly on the processes governing the variation in species assemblages among sites (or samples). Ordinations allow visualization of the variation in community data across two or more axes. Pairwise differences between samples are calculated by resemblance coefficients (similarity, dissimilarity or distance) which translate into spatial distance on ordination plots. Samples sharing many species in common (with similar relative abundances) are close together in ordination space. Samples with few shared species (and very different relative abundance) are far apart in ordination space.

Because the choice of resemblance coefficient can influence ordination results, species composition was assessed using two different distance matrices, one based on species presence-absence (S_8; Sørenson 1948) and one based on Hellinger Distance (D_{17}; Rao 1995). The S_8 coefficient gives equal weight to rare and common species. The D_{17} metric gives less weight to species with low abundance (rare species) than abundant (common) species. Hellinger distance is also highly recommended for ordination of species abundance data (Legendre and Gallagher 2001; Rao 1995).

To test for differences in arthropod species composition between revegetation and control locations, we performed Permutational Multivariate Analysis of Variance (PERMANOVA; Anderson 2001) tests. Study site was included as a block for all analyses. All tests were run with 9,999 permutations ($\alpha = 0.10$) using the vegan community ecology package (Oksanen et al. 2018).

To extract and summarise the variation in species assemblages related to revegetation treatments, we conducted redundancy analysis (RDA; Legendre and Legendre 2012). RDA is an ordination technique that allows formal hypothesis testing around ecological relationships. In our case, we relate two data sets containing standardized species abundances from each pitfall trap location (matrices of spider and beetle species abundances) to a data set containing explanatory site/vegetation data at each pitfall trap location (Appendix H). RDA is a direct extension of regression analysis to model multivariate response data. Initially, the RDA was tested using a global model that included all explanatory variables (treatment type, site, cover of LOM cover, and cover of substrate classes). A final model was selected that reduced the number of explanatory variables to contain those having a significant effect on species assemblages. Significance of the final model, axes and explanatory variables were tested (α = 0.10) with 9,999 permutations. RDA was performed using the vegan package for community ecology (Oksanen et al. 2018).

Ordination plots display sampling points for each revegetation and control polygon at each study site. Species correlations with each axis of the ordination plot are overlaid as vectors ($p<0.1$) to aid in interpretation of differences between species assemblages.

4.6.3 Birds

Bird analyses were limited to passerines (e.g., songbirds, swallows), swifts, and hummingbirds detected during point count surveys. For ease of reading throughout the report we collectively refer to these as "songbirds", and most bird detections were indeed of true songbirds. We limit analyses to detections within 30 m of the point count centre due to the very small widths of revegetation treatments that were applied. Extending detections to include observations >30 m precludes any discussion of treatment effects. Birds detected as fly-overs were excluded from analyses, as these individuals may not be utilizing the treatment area containing the point count; the exception being swallows, swifts and hummingbirds which are included as they are almost exclusively detected as they fly over the treatment area.

Species richness and diversity

Analyses were completed for treatment and control points. Data were summarized by calculating the maximum count of individuals per species over both visits (when applicable) to that station, such that the statistical unit was the point count, which was replicated within habitats and sites (Appendix D).

Richness (q) was calculated as the total number of songbird species detected per point count station. Diversity (Shannon's entropy index (H)) was calculated for songbirds as described in Legendre and Legendre (2012).

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

We conducted our analyses with the statistics program R (R Core Team 2018). P-values under 0.1 were considered significant.

Species composition and assemblage similarity

Bird communities were assessed through ordinations and qualitative summaries. Non-metric multidimensional (nMDS) scaling plots were also used to visually assess bird community data. The experimental unit for nMDS ordinations was the habitat type. The method of pooling data was as described for richness and diversity. Singletons (species present only once in the dataset) were not removed from the dataset, as they represented a large proportion of the data. The response variable of the nMDS plot was a resemblance matrix calculated using Bray-Curtis coefficients, and bird community data were not transformed (Clarke 1993). nMDS plot construction incorporated 100 restarts. All nMDS graphs had a stress greater than 0.2, and therefore must be interpreted with caution as 2-dimensonal representation of higher dimensional trends (Clarke 1993). This is primarily a product of the large number of singletons present in the data.

4.6.4 Bats

Bat presence and activity was assessed by analyzing triggered recordings from Wildlife Acoustics Song Meter units using their automatic classification software (Kaleidoscope Pro v. 4.5.4). The software program is a quick and effective tool for analyzing a large volume of recordings, and results are easily exported for further analysis. Kaleidoscope utilizes classifiers developed from libraries of species-verified recordings to generate complex algorithms used in the automated identification process. Species classifiers can be selected to match the expected bat fauna in an area. The classifiers for 11 species that have been confirmed in the West Kootenays were selected for use in analysis of 2018 Wildlife Physical Works pre-treatment data. Auto ID analysis is intended for use on recordings of single bats in a low clutter environment, but some environmental (e.g., rain, wind, surface echoes, temperature changes, etc.) and biological (e.g., number of bats present, distance of bats, etc.) factors cannot be controlled and thus recording quality may vary. In addition, the acoustic signatures of many bat species overlap in their frequency ranges, making it difficult to confidently differentiate some species (Table 9-2; also, Szewczak et al. 2011a,b). Thus, we present our bat detections as "indicative" rather than definitive. Data collected by autonomous recording devices do not provide an indication of the number of individual bats present in a given area and the assignment of species is based on a probability that the species is present.

5.0 RESULTS

5.1 Reservoir Conditions

Reservoir elevations in 2018 were lowest in February to April, hitting the lowest yearly point on March 29, 2018 (429.18 m ASL; Figure 5-1). Water levels increased after that, peaking on July 13, 2018 (439.73 m ASL). From a summertime peak, water levels typically drop until October/November when a secondary peak sometimes occurs. From that secondary peak reservoir elevations then lower until the annual minima.

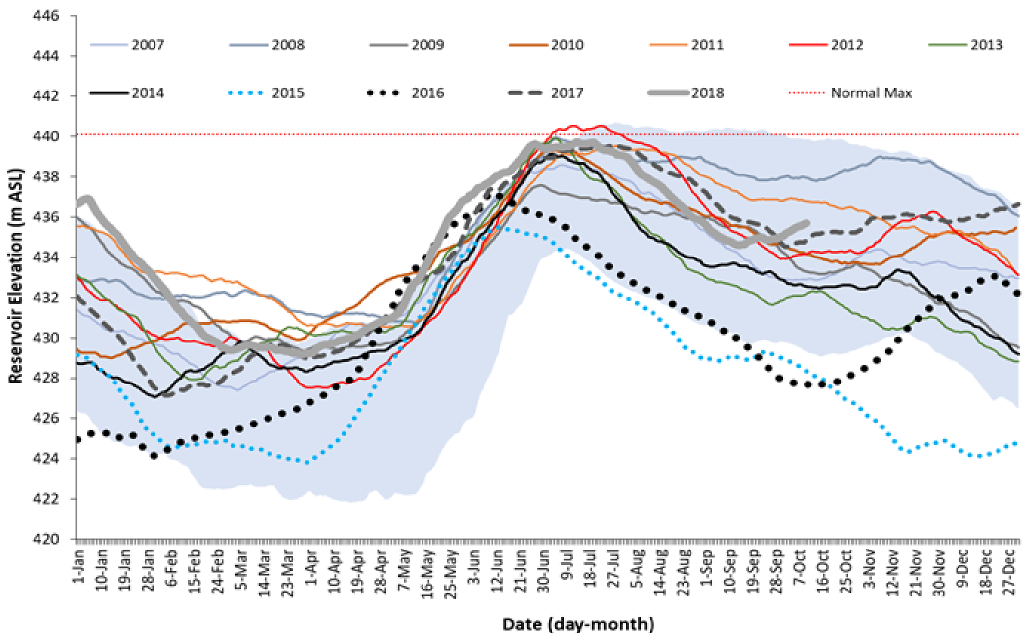

Figure 5-1: Arrow Lakes Reservoir elevations for 2008 to 2018. The 10th and 90th percentiles are shown for 1969-2018 (shaded area); m ASL= metres above sea level

5.2 Revegetation Treatments

The revegetation prescriptions for the treatment polygons sampled in each study area during CLBMON-11B1 in 2018 are summarized in Table 5-1. Data collected under CLBMON-12 (Miller et al. 2018) indicated that transplant success was highly variable in the drawdown zone. The success rate for black cottonwood stakes at Lower Inonoaklin and Edgewood South was high. Stake survival was low at Burton Creek and variable at other sites. Willow and dogwood stake survival was nil among sites sampled in 2018.

Sedge seedling plugs were most successful within polygons at Edgewood North, East Arrow, and Lower Inonoaklin. However, survivorship of sedge plugs varied greatly among polygons within each site, such that the lowest densities were also observed at Lower Inonoaklin and Edgewood North. There were several factors listed that might limit transplant success, including operational effects related to inundation (e.g., erosion, deposition, wave scouring, wood debris scouring, and drought conditions) and non-operational effects (e.g. substrates, nutrients, rodent damage, ATV traffic, other human disturbances).

Table 5-1: Summary table of revegetation prescriptions and survivorship in treatment areas sampled under CLBMON-11B1 in 2018. Bold values indicate increased vegetation density. HPL= hand-planted live stake, EPL= excavator-planted live stake, MBL= live stakes in a modified brush layer, PS= sedge plug. Transplant species prefix s= shrub, g= graminoid. Data source: CLBMON-12 (Miller et al. 2018).

Site	CLBWORKS-2 polygon	Area (Ha)	Treatment*	Code	Transplant Species
Burton	2009_25	1.216	stake	EPL & HPL	s - Black cottonwood s - Willow
	2009_64	2.343	graminoid	PS	g - Columbia sedge g - Kellogg's sedge g - Water sedge g - Wool-grass
East Arrow Park	2009_41	0.739	graminoid	PS	g - Columbia sedge
	2009_49	1.804	graminoid	PS	g - Columbia sedge g - Kellogg's sedge
	2010_11	1.314	graminoid	PS	g - Columbia sedge g - Kellogg's sedge
Edgewood South	2009_1	0.179	stake	EPL	s - Black cottonwood s - Willow
	2009_3	0.649	stake	EPL	s - Black cottonwood s - Willow
Edgewood North	2009_7	1.445	graminoid	PS	g - Columbia sedge g - Kellogg's sedge g - Water sedge g - Wool-grass
	2009_9	1.268	graminoid	PS	g - Columbia sedge g - Kellogg's sedge g - Small-flowered bulrush g - Water sedge
	2011_31	0.205	graminoid	PS & HPL	g - Kellogg's sedge g - Water sedge g - Wool-grass s - Red-osier dogwood
Lower Inonoaklin	2009_13	0.535	stake	PS & EPL	g - Columbia sedge s - Black cottonwood s - Willow
	2009_16	0.177	stake	PS & EPL	s - Black cottonwood s - Willow
	2009_18	0.386	stake	PS, EPL & HPL	s - Black cottonwood s - Willow
	2009_19	0.433	graminoid	PS	g - Columbia sedge
	2011_23	0.722	graminoid	PS	g - Kellogg's sedge
12 Mile	2009_87	0.085	graminoid	PS	g - Columbia sedge g - Kellogg's sedge
	2010_RR11_A	0.086	stake	MBL	s - Black cottonwood
	2010_RR11_B	0.106	stake	HPL	s - Black cottonwood
	2010_RR9	2.168	stake	EPL	s - Black cottonwood
	2010_RR12	0.093	stake	MBL	s - Black cottonwood
8 Mile	2010_RR5_A	2.702	stake	EPL	s - Black cottonwood s - Red-osier dogwood
	2010_RR5_C	0.182	stake	HPL	s - Black cottonwood
9 Mile	2010_RR8	2.414	stake	HPL	s - Black cottonwood s - Red-osier dogwood
McKay	2010_RR2_A	0.314	stake	EPL	s - Black cottonwood
	2010_RR2_C	0.058	stake	EPL & HPL	s - Black cottonwood
	2010_RR2_E	0.323	stake	EPL	s - Black cottonwood
	2010_RR4_A	0.135	stake	EPL	s - Black cottonwood
	2010_RR4_B	0.204	stake	EPL	s - Black cottonwood
	2010_RR4_C	0.548	stake	EPL	s - Black cottonwood

*treatment category was assigned based on the dominant treatment prescription for each polygon.

5.3 Arthropods

A total of 5,775 individual arthropods were collected in the 2018 diversity pitfall samples (excluding Acari and Collembola, which were not counted due to the vast numbers present).

5.3.1 Relative abundance (CPUE)

Overall there was no consistent pattern in how treatment type (graminoid, stake, or control) affected the relative abundance (CPUE) of arthropods (Figure 5-2). At 12 Mile and Edgewood South, CPUE seemed to increase in stake revegetated plots, but CPUE trends at 9 Mile showed the reverse. CPUE in revegetated graminoid plots seemed to overlap with that in control plots, except for a potential increase in CPUE in the graminoid plot in Burton relative to the CPUE in the control plot.

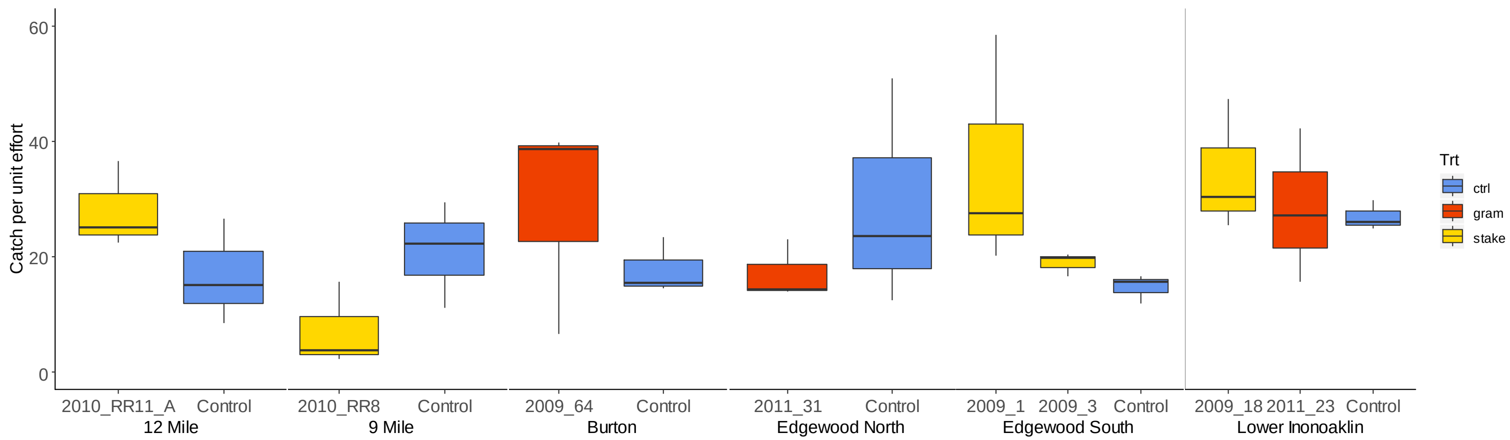

Figure 5-2. Arthropod catch per unit effort (CPUE) as a response to treatment type (Trt): graminoid (gram; n=3), stake (n=5), and control (ctrl; n=6). Samples were collected from diversity pitfall traps located in each polygon (n=3) in 2018.

5.3.1 Richness, diversity, and relative abundance

Hymenoptera and Diptera

We captured a total of 1,616 Hymenopterans comprising 39 families (Figure 5-3) and 22,916 Dipterans comprising 48 families (Figure 5-4) from Malaise traps. This includes tents located in stake (n=4), graminoid (n=1), and control (n=6) areas in the first collection period and stake (n=2) and control (n=3) areas from the second collection period.

The Hymenopteran family Ichneumonidae dominated Malaise trap samples and was in the top three families found at every site except for Burton in the first collection (Appendix I). Parasitoid wasps (including Ichneumonidae) were a common feature for most sites and treatments. Social and solitary (non-parasitic) wasps were less frequently selected within the top three families from the samples, but this had seemingly no relation to site or revegetation treatment. At only one site (a stake polygon at 12 Mile) was a non-wasp family included in the top three families present (Andrenidae; mining bees).

The most abundant fly family (Chironomidae) was within the top three families found at every site. There were some possible site-specific patterns of presence for some families (for example, muscid flies were in the top three at both revegetation and control polygons at 9 Mile specifically; mycetophilid flies showed a similar pattern at 12 Mile). However, there were no clear trends of treatment effect on these families or any other obvious biologically relevant differences in the proportion of dominant families between stake, graminoid, or control sites.

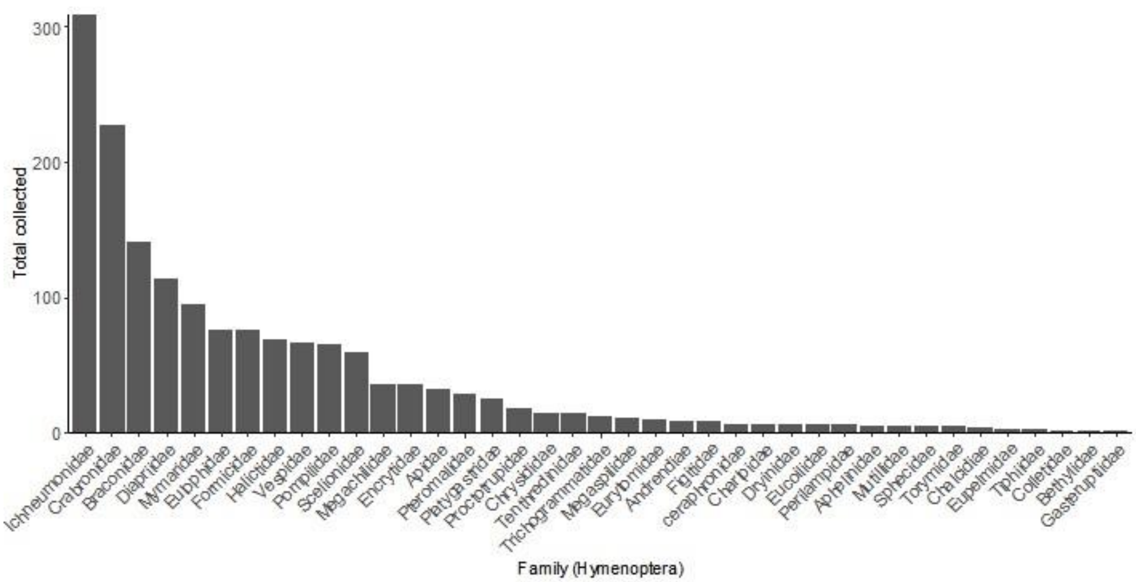

Figure 5-3. Hymenoptera families and associated abundances (not standardized to trapping effort) collected from Malaise traps (n=16) in 2018.

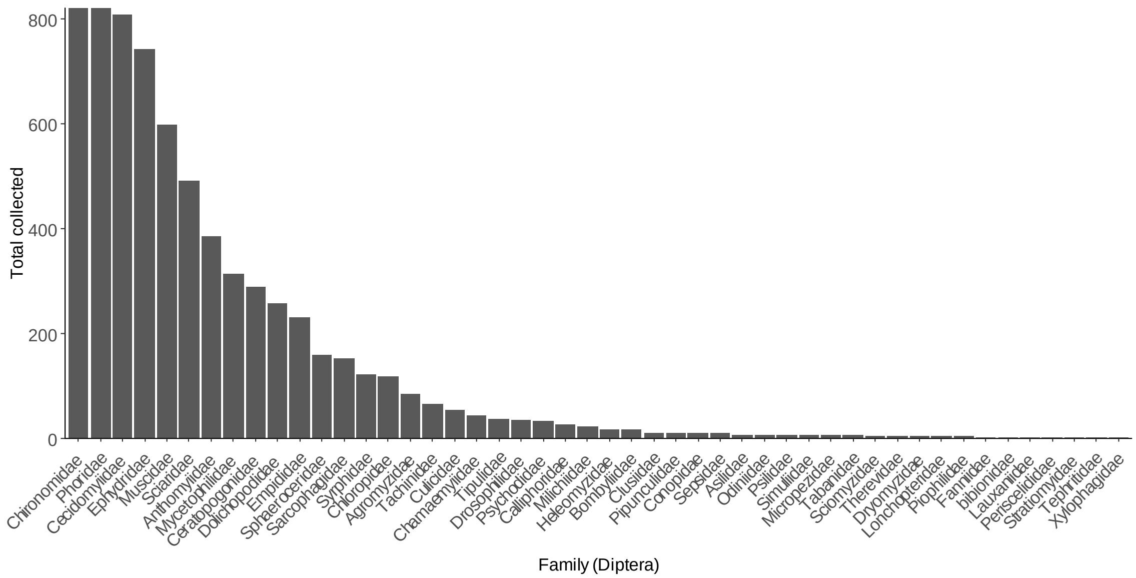

Figure 5-4. Diptera families and associated abundances (not standardized to trapping effort) collected from Malaise traps (n=16) in 2018. Abundances are truncated for Chironomidae (n=23791) and Phoridae (n=1788), which vastly exceeded the graph cap of 820 individuals.

Araneae

We captured a total of 151 adult and 186 immature spiders comprising 34 known species and one unknown species (of the genus *Castianeira*) from diversity pitfall traps (Figure 5-5). This includes traps located in stake (n=5), graminoid (n=3), and control (n=6) areas in the first collection period and stake (n=3) and control (n=4) areas in the second collection period. No adventive (introduced) spiders were collected from revegetation treatments or control polygons. The most numerous spider species collected were *Pardosa altamontis* and *P. moesta*, which are widespread, open-habitat, ground-hunting wolf spiders.

No particularly strong pattern emerged for treatment effect on spider diversity or rarefied richness per 24-hour period (Figure 5-6 and Figure 5-7). Many sites showed no real difference in diversity or richness in stake, graminoid, or control treatments. There appeared to be an increase in spider diversity in the control at Burton Creek relative to the graminoid revegetation treatment. At 12 Mile, 9 Mile, and to a lesser extent Burton Creek, there was a trend for higher spider species richness in control relative to revegetation (both graminoid and stake) treatments. However, Edgewood North showed a reversed trend for increased spider richness in the graminoid polygon relative to the control.

The stake revegetation polygon at 9 Mile and one of the stake revegetation polygons at Lower Inonoaklin showed a lower relative abundance per 24-hour period (CPUE) relative to that in the control (Figure 5-8). However, the other stake polygon at Lower Inonoaklin did not show a similar trend. Otherwise, no obvious patterns of treatment on spider abundance emerged.

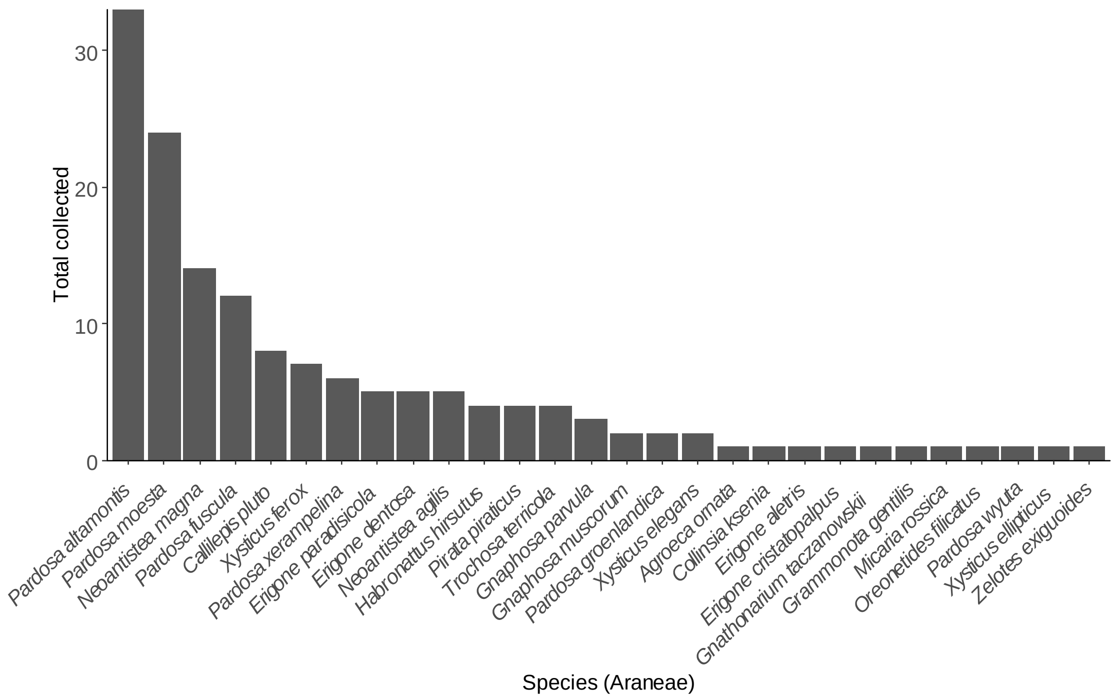

Figure 5-5. Araneae species and associated abundances collected in diversity pitfall traps (n=62) in 2018. Totals not standardized to trapping effort.

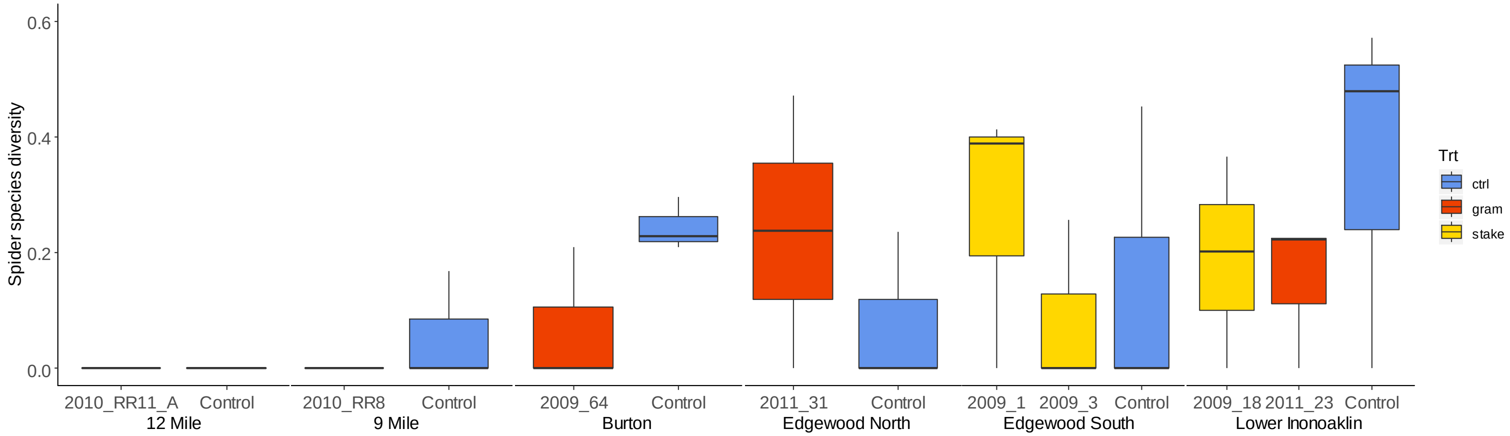

Figure 5-6. Araneae species diversity per 24-hour period as a response to treatment type (Trt): graminoid (gram; n=3), stake (n=5), and control (ctrl; n=6). Samples were collected from diversity pitfall traps (n=3) located in each polygon in 2018.

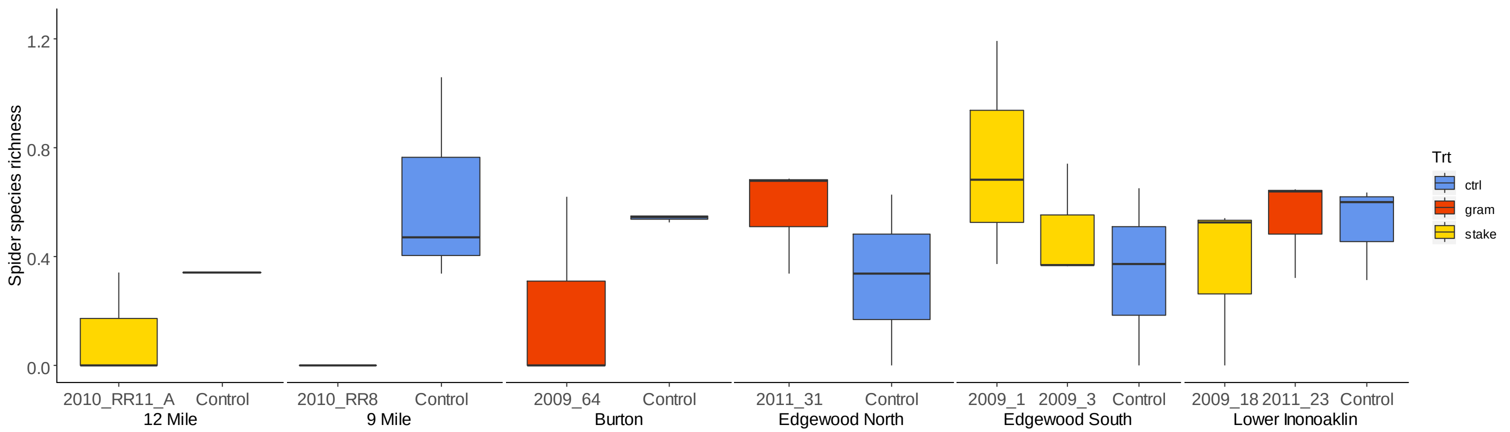

Figure 5-7. Araneae species richness (rarefied) per 24-hour period as a response to treatment type (Trt): graminoid (gram; n=3), stake (n=5), and control (ctrl; n=6). Samples were collected from diversity pitfall traps (n=3) located in each polygon in 2018.

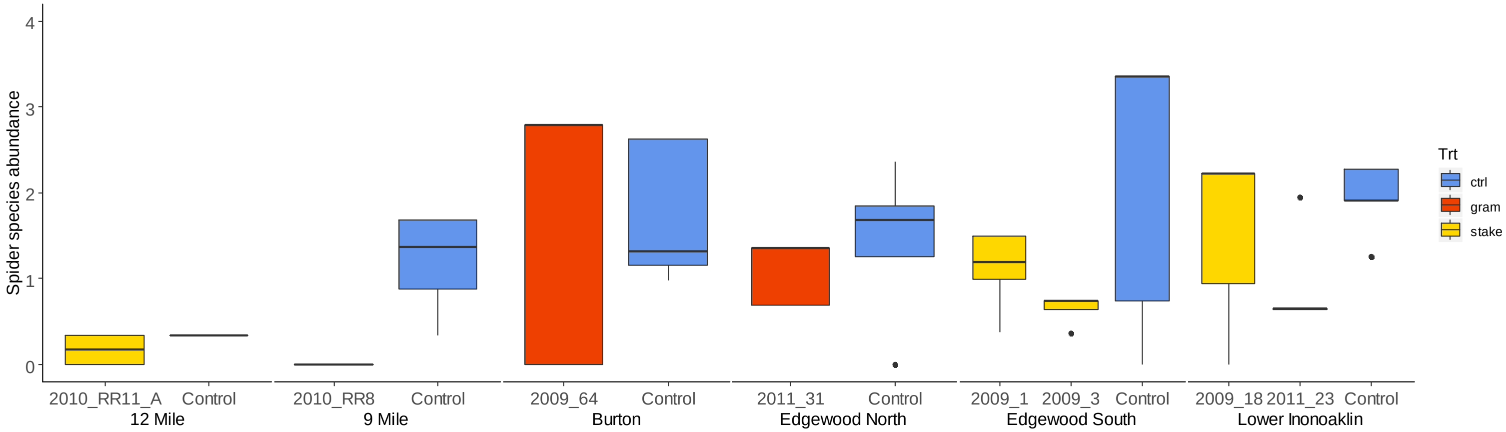

Figure 5-8. Araneae species abundance per 24-hour period (CPUE) as a response to treatment type (Trt): graminoid (gram; n=3), stake (n=5), and control (ctrl; n=6). Samples were collected from diversity pitfall traps (n=3) located in each polygon in 2018.

Coleoptera

We captured a total of 731 adult beetles comprising 22 families from diversity pitfall traps (Figure 5-9). This includes traps located in stake (n=5), graminoid (n=3), and control (n=6) areas in the first collection period and stake (n=3) and control (n=4) areas from the second collection period. Carabidae (Ground beetles) was the most numerous beetle family collected.

Coleoptera family diversity per 24-hour period (Figure 5-10) was largely the same between treatment and control polygons at each site. The exception was an apparently higher diversity in control polygons relative to stake polygons at 12 Mile and 9 Mile. There also appeared to be between-site variation in diversity, with a lower overall diversity at northern (9 Mile and 12 Mile) compared to southern sites (Lower Inonoaklin and Edgewood South). There were no clear trends in treatment effect on Coleoptera rarefied richness per 24-hour period (Figure 5-11) at any of the sites.

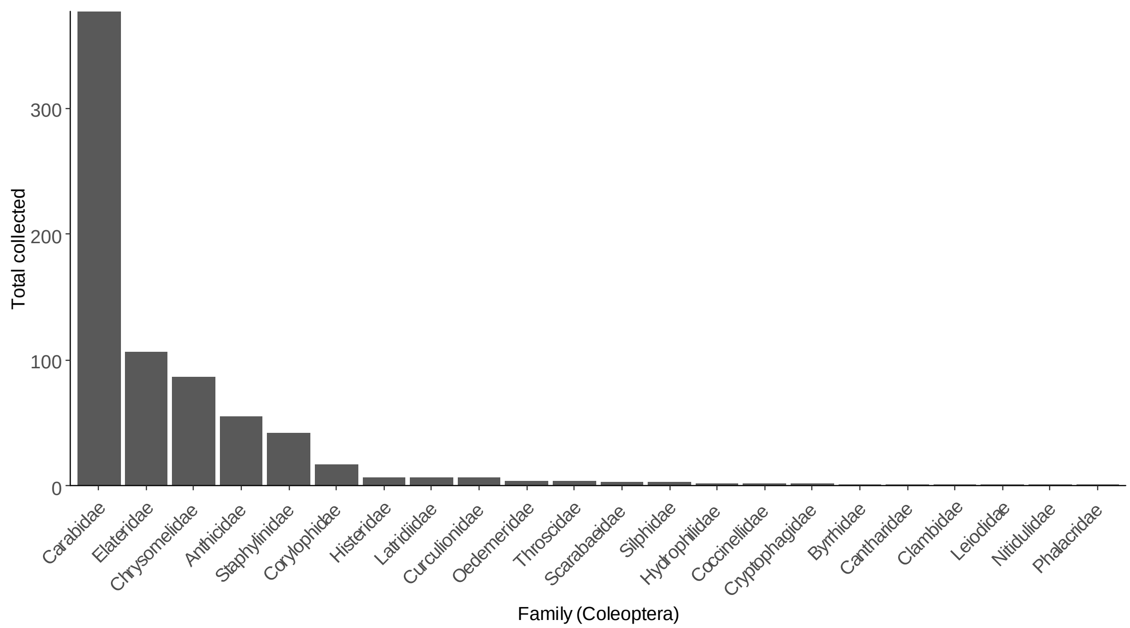

Figure 5-9. Coleoptera families and associated abundances collected in diversity pitfall traps (n=62) in 2018. Totals were not standardized to trapping effort.

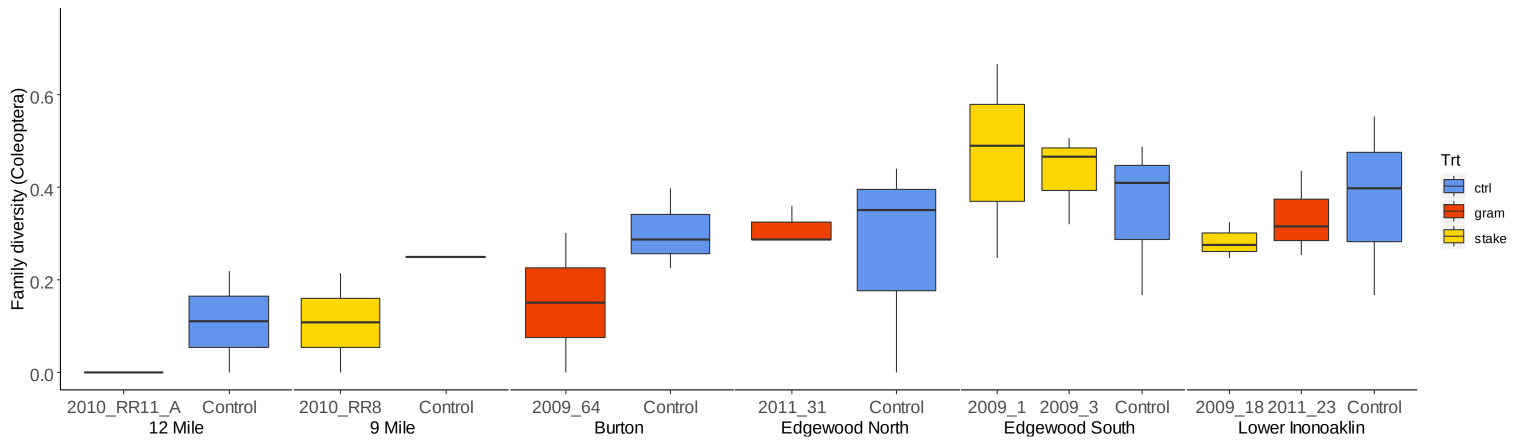

Figure 5-10. Coleoptera family diversity per 24-hour period as a response to treatment type (Trt): graminoid (gram; n=3), stake (n=5), and control (ctrl; n=6). Samples were collected from diversity pitfall traps (n=3) located in each polygon in 2018.

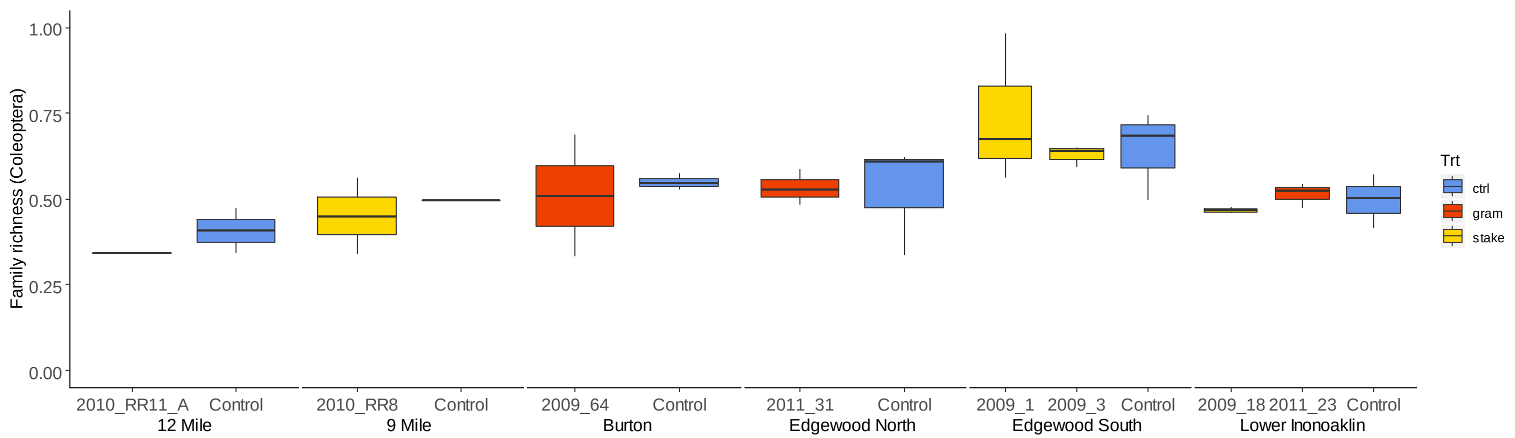

Figure 5-11. Coleoptera familial richness per 24-hour period as a response to treatment type (Trt): graminoid (gram; n=3), stake (n=5), and control (ctrl; n=6). Samples were collected from diversity pitfall traps (n=3) located in each polygon in 2018.

Coleoptera: Carabidae

We captured a total of 377 adult and 13 juvenile carabid beetles comprising 40 species from diversity pitfall traps (Figure 5-12). This includes traps located in stake (n=5), graminoid (n=3), and control (n=6) areas from the first collection period and stake (n=3) and control (n=4) areas from the second collection period. Nearly 20 per cent of all ground beetles collected were adventive species introduced to Canada (83 specimens of nine adventive species).

There was a trend for higher carabid species diversity per 24-hour period in graminoid plots at Lower Inonoaklin, Edgewood North, and Burton Creek compared to control plots (Figure 5-13). Carabid species diversity was also higher at one of the stake revegetation polygons located in Lower Inonoaklin compared to that in the control. However, no other site showed an increase in carabid species diversity in stake polygons, and one site (9 Mile) showed the trend in reverse.

Trends in carabid abundance per 24-hour period (CPUE) between treatment types were more subtle (Figure 5-14). Carabid abundance at Burton Creek was higher in the graminoid plot compared to the control, and Lower Inonoaklin showed a higher carabid abundance in the stake plot compared to the control (carabid abundance in the graminoid plot overlapped with abundance in the control). Otherwise, abundances in stake and graminoid polygons at other sites largely overlapped with abundances in the controls.

While carabid rarefied richness per 24-hour period in both the revegetation treatments and the control largely overlapped within each site (Figure 5-15), Burton Creek and Edgewood North showed a higher carabid richness in graminoid revegetation treatments compared to controls, and both 12 Mile and 9 Mile showed a lower richness in stake polygons compared to controls.

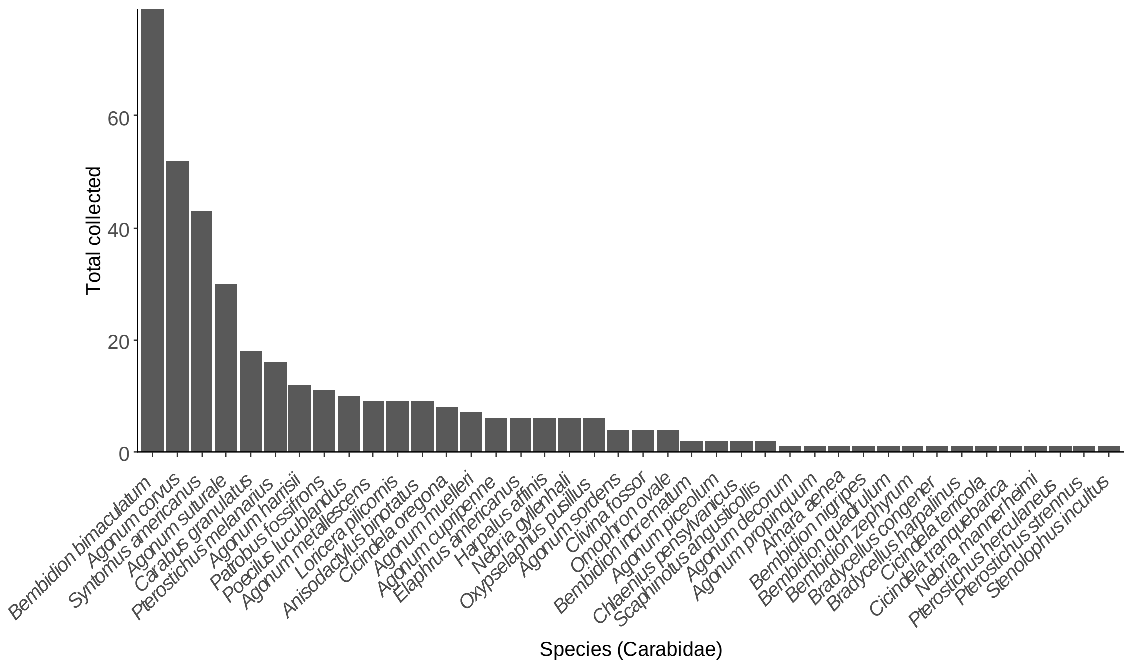

Figure 5-12. Species and abundances of carabid beetles collected in diversity pitfall traps in 2018 (n=62). Totals were not standardized to trapping effort.

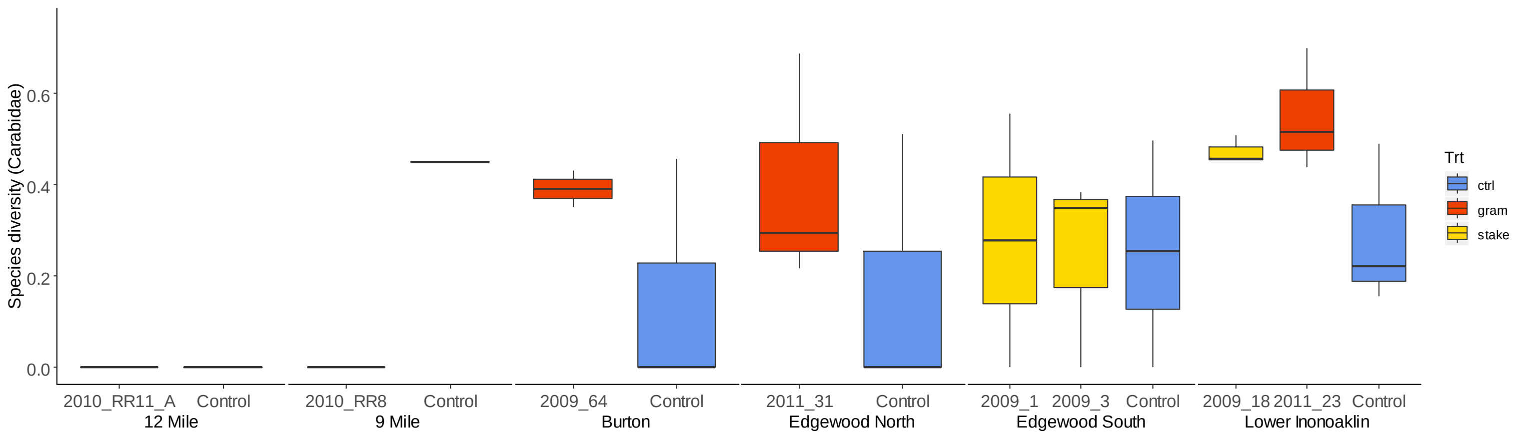

Figure 5-13. Carabid species diversity per 24-hour period as a response to treatment type (Trt): graminoid (gram; n=3), stake (n=5), and control (ctrl; n=6). Samples were collected from diversity pitfall traps (n=3) located in each polygon in 2018.

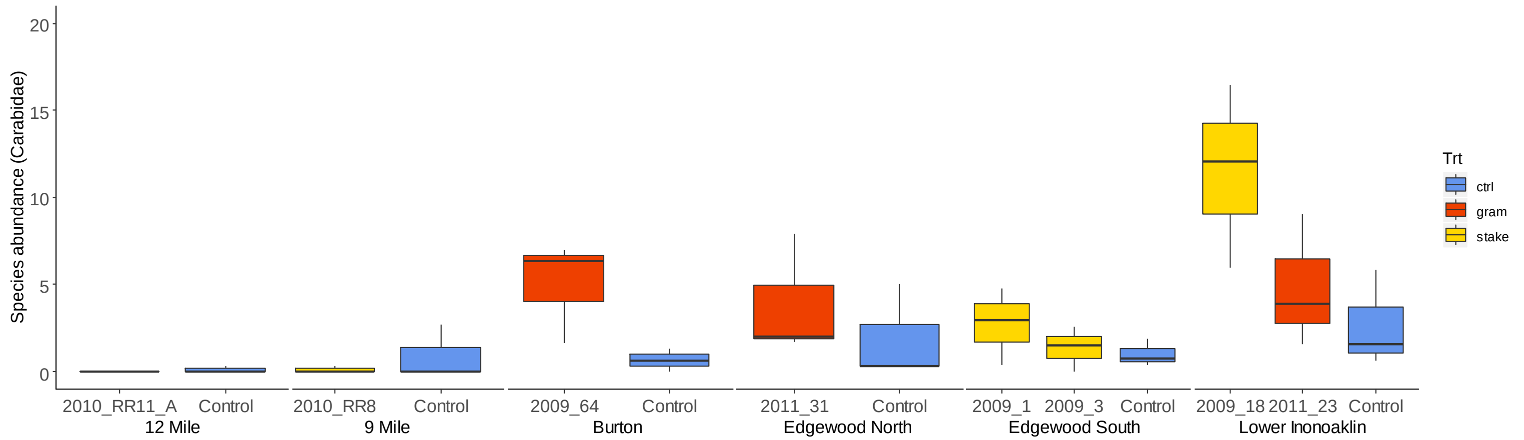

Figure 5-14. Carabid species abundance per 24-hour period (CPUE) as a response to treatment type (Trt): graminoid (gram; n=3), stake (n=5), and control (ctrl; n=6). Samples were collected from diversity pitfall traps (n=3) located in each polygon in 2018.

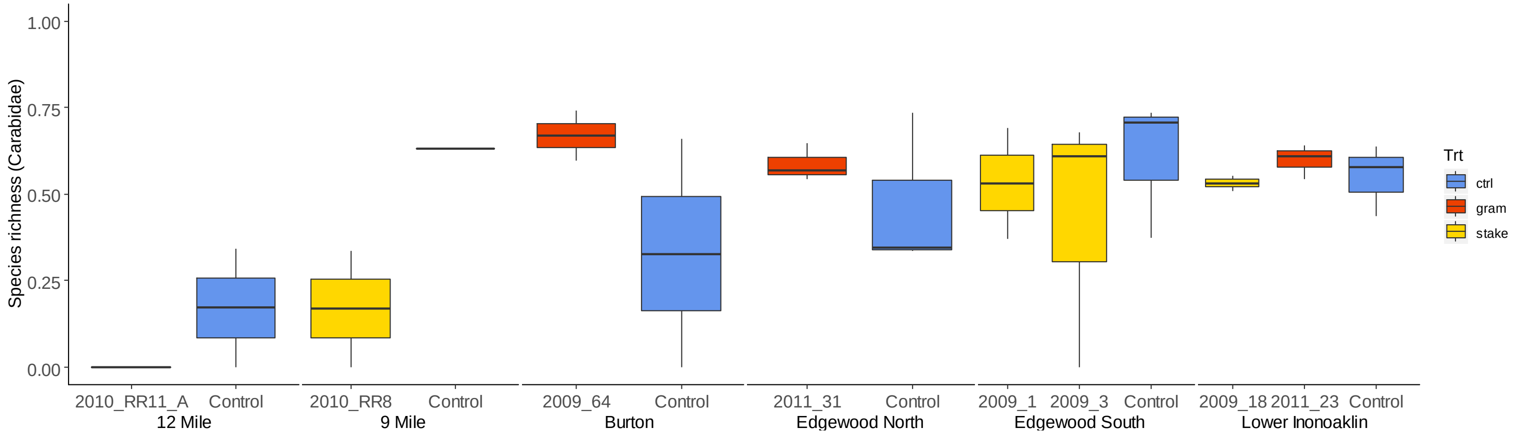

Figure 5-15. Carabid species richness (rarefied) per 24-hour period as a response to treatment type (Trt): graminoid (gram; n=3), stake (n=5), and control (ctrl; n=6). Samples were collected from diversity pitfall traps (n=3) located in each polygon in 2018.

5.3.2 Biomass

During the first collection period, we gathered biomass data from pitfall traps located in graminoid (n=2), stake (n=5), and control (n=6) areas (Figure 5-16). Trends in arthropod biomass (mg/hr) showed no clear pattern of treatment effect. Biomass was lower in graminoid plots in Edgewood North compared to control plots, but the trend was reversed in Lower Inonoaklin. One stake polygon at Edgewood South showed a potentially higher biomass than the control, but this trend was not consistent with biomass in both stake polygons at the site. 9 Mile showed a lower biomass overall compared to other sites. Otherwise, biomass in treatment polygons overlapped with biomass in the controls.

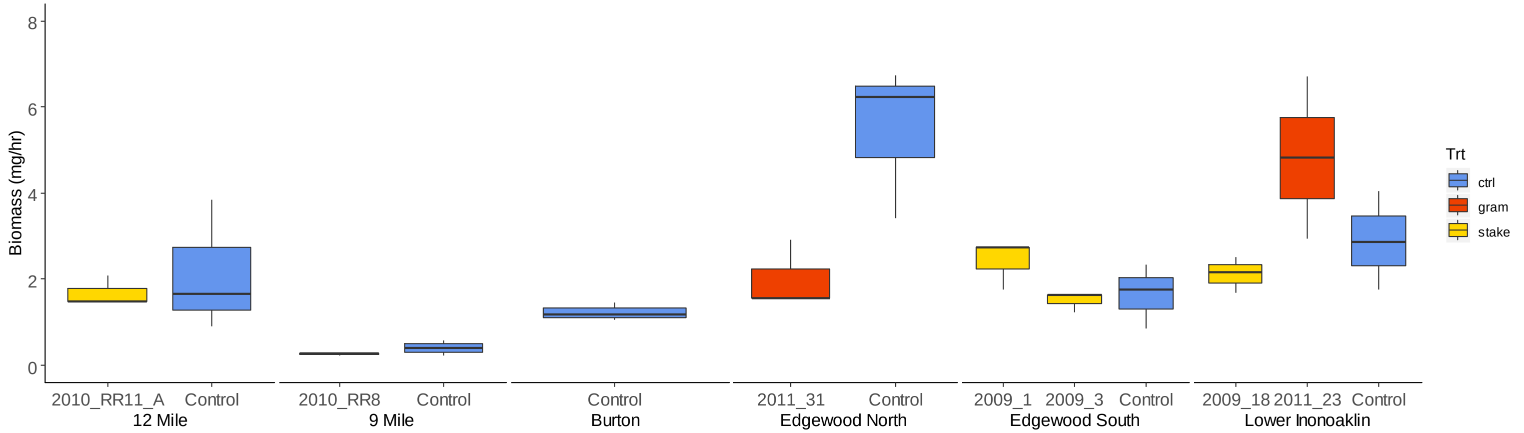

Figure 5-16. The amount of arthropod biomass (measured in mg/hr) as a response to treatment type (Trt): graminoid (gram; n=2), stake (n=5), and control (ctrl; n=6). Samples were collected from biomass pitfall traps (n=3; except for n=2 at 2011_23 in Lower Inonoaklin) located in each polygon in 2018.

5.3.3 Composition

PERMANOVA tests

Ground beetle species were significantly different among control, stake, and graminoid revegetation treatments, regardless of resemblance coefficient (S_8: $F_{(2,33)} = 2.12$, $p = 0.005$; D_{17}: $F_{(2,33)} = 1.67$, $p = 0.007$), blocking for site differences. However, spider species assemblages did not significantly differ among control, stake, and graminoid revegetation treatments for either resemblance coefficient (S_8: $F_{(2,31)} = 1.27$, $p = 0.2$; D_{17}: $F_{(2,31)} = 1.18$, $p = 0.2$), blocking for site differences.

Redundancy Analyses

The interaction between revegetation treatment and study site influenced beetle and spider species assemblages, regardless of resemblance coefficient (Table 5-2). Substrate covers and per cent LOM cover were not retained in the model due to lack of relationship with beetle and spider assemblages. Final models retained only revegetation treatment, study site, and the interaction between treatment and site. Despite significance of the models, the variance explained was relatively low for all RDAs (less than 20% of the variance in assemblages was explained by each axis), suggesting that other unmeasured factors may better explain the structure of spider and beetle species assemblages than treatment and study site (Figure 5-17; Figure 5-18). Improved solutions may be found with additional species-level data.

When rare species were given the same weight as common species (S_8 coefficient), spider and beetle species assemblages formed two clear groups: one of control polygons and one of revegetation polygons. Graminoid and live stake revegetation treatments did not appear different in species composition in the RDAs. However, when species abundances were considered (D_{17} coefficient), site-specific differences became more apparent. The assemblages of the treatments at Lower Inonoaklin (LI) were distinct compared to the species assemblages of the other sampling locations. There were numerous different beetle species found to be correlated with the revegetation treatments and controls (Figure 5-17). However, only one spider species was found to be correlated to revegetation treatments (*Neoantistea agilis*; Figure 5-18).

Table 5-2. Results of redundancy analyses of the effect of revegetation treatment (control, graminoid, stake) and study site on spider (Araneae) and ground beetle (Carabidae) assemblages.

Taxon	Coefficient	Term	df	Variance	F	p-value
Araneae	S_8	Site	5	0.48	1.89	0.001 ***
		Treatment	2	0.13	1.30	0.141
		Interaction	4	0.27	1.37	0.061 *
		Residuals	22	1.12		
	D_{17}	Site	5	0.21	1.98	0.002 **
		Treatment	2	0.04	0.99	0.441
		Interaction	4	0.11	1.30	0.060 *
		Residuals	22	0.48		
Carabidae	S_8	Site	5	0.85	2.47	0.001 ***

Taxon	Coefficient	Term	df	Variance	F	p-value
		Treatment	2	0.25	1.80	0.007 **
		Interaction	4	0.37	1.36	0.037 *
		Residuals	24	1.66		
	D_{17}	Site	5	0.22	2.31	0.001 ***
		Treatment	2	0.07	1.93	0.003 **
		Interaction	4	0.10	1.40	0.022 *
		Residuals	24	0.45		

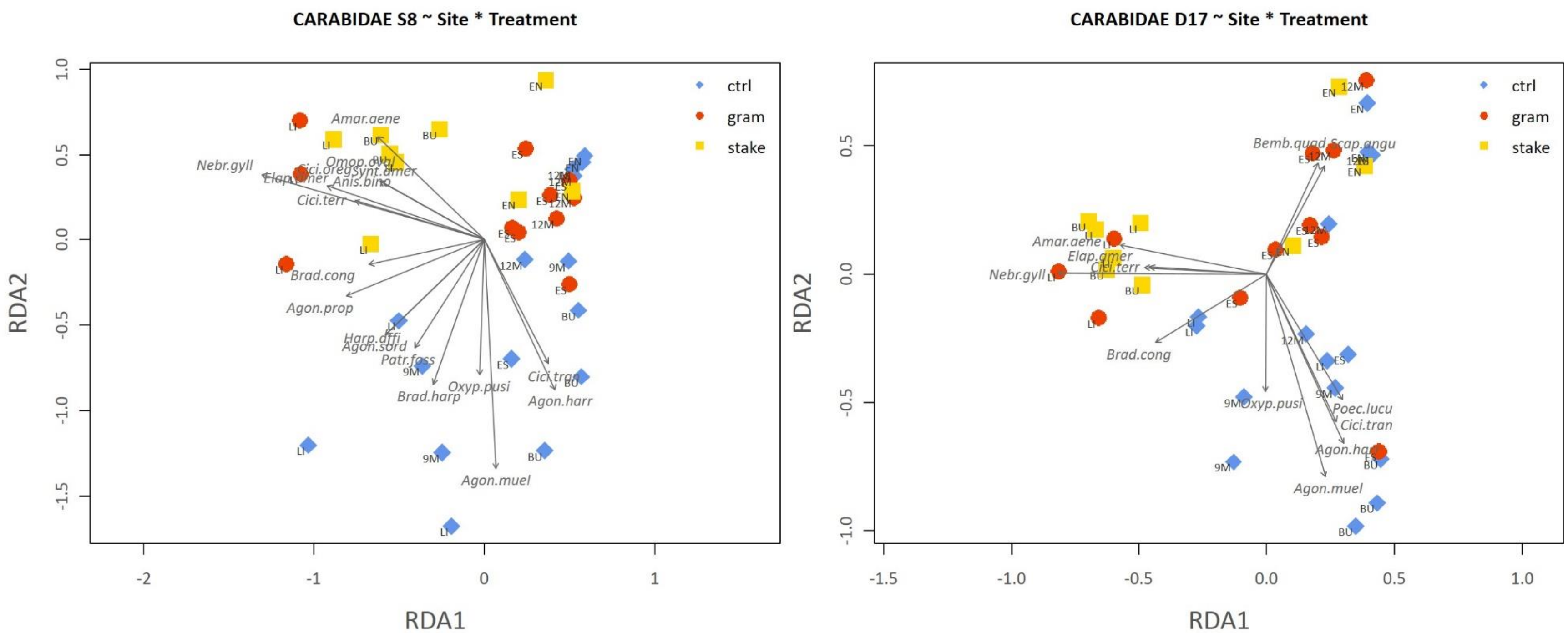

Figure 5-17 Redundancy Analysis (RDA) ordination of carabid beetle species assemblages collected in pitfall traps in 2018, showing relationships among treatments and sites. Left: Sorenson coefficient; axis 1 and axis 2 explain 16.5% and 9.7% of the constrained variance. Right: Hellinger coefficient; axis 1 and axis 2 explain 13.9% and 8.6% of the constrained variance. Significant ($p<0.1$) species vectors (grey arrows) are overlaid for interpretation of relationship with samples (length proportional to strength of relationship). Labels are staggered slightly if plotted in the same location. Site codes: BU= Burton, ES= Edgewood South, EN= Edgewood North, LI= Lower Inonoaklin; Treatments: 'ctrl' = drawdown zone control, 'gram' = graminoid revegetation, and 'stake' = live stake revegetation.

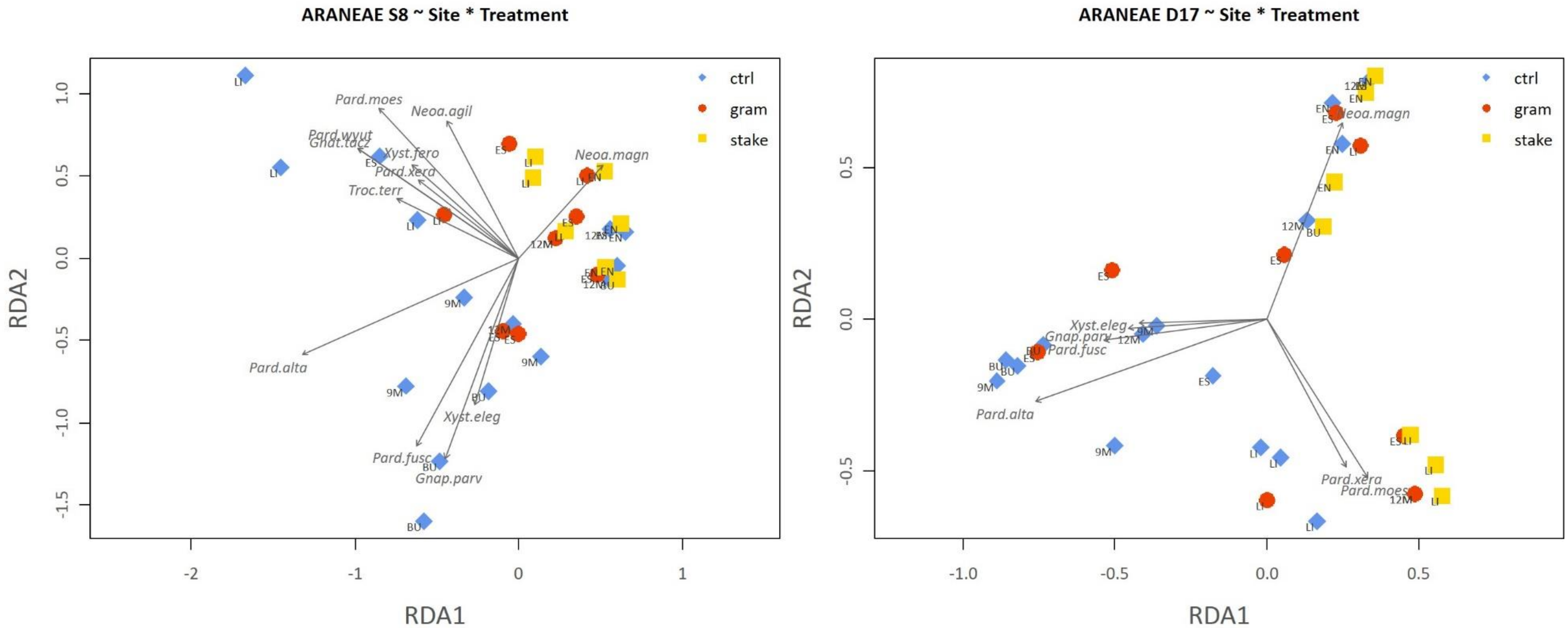

Figure 5-18 Redundancy Analysis (RDA) ordination of Araneae species assemblages collected in pitfall traps in 2018, showing relationships among treatments and sites. Left: Sorenson coefficient; axis 1 and axis 2 explain 13.5% and 10% of the constrained variance. Right: Hellinger coefficient; axis 1 and axis 2 explain 11% and 8.8% of the constrained variance. Species significantly correlated with ordination axes (p<0.1) are drawn with vectors (grey) proportional to strength of relationship. Labels are staggered slightly if plotted in the same location. Site codes: BU= Burton, ES= Edgewood South, EN= Edgewood North, LI= Lower Inonoaklin; Treatments: 'ctrl' = drawdown zone control, 'gram' = graminoid revegetation, and 'stake' = live stake revegetation. Note: environmental variables were not significantly correlated with the ordination axes (p>0.1)

5.4 Birds

5.4.1 Revegetation Effects: Species richness and diversity

When richness per point count was compared for graminoid (sedge plug) and live stake (cottonwood) revegetation treatments to control plots, there were no significant differences (χ^2=2.51, df=2, p=0.29). In most cases only one type of treatment plot existed at a study site (either graminoid or stake). While there was no treatment effect on richness, some site-specific patterns were revealed (Figure 5-19):

- Within 8 Mile and 9 Mile (Revelstoke Reach), point count richness was significantly higher within stake treatment points than controls. At 8 Mile, species within the control stations consisted of hummingbirds and Tree Swallow. In comparison, the treatments had a variety of taxa including sparrows, warblers, flycatchers, and other species that may utilize stakes and other shrubs. While control sites at 9 Mile were slightly richer than the former site and included warblers and sparrows, the stake treatment still had greater richness due to occurrences of more aerial insectivores, and both shrub and grassland nesting bird species (e.g., Western Meadowlark and Willow Flycatcher).
- At Edgewood North, control stations showed higher species richness than treatment stations. Overall, treatment and control had the same number of bird species detected. It is probable that richness does not truly differ at this site, but values may be inflated for controls due to the presence of forest birds detected from the forest-drawdown zone edge (e.g., Golden-crowned Kinglet, Hammond's Flycatcher, Western Tanager).

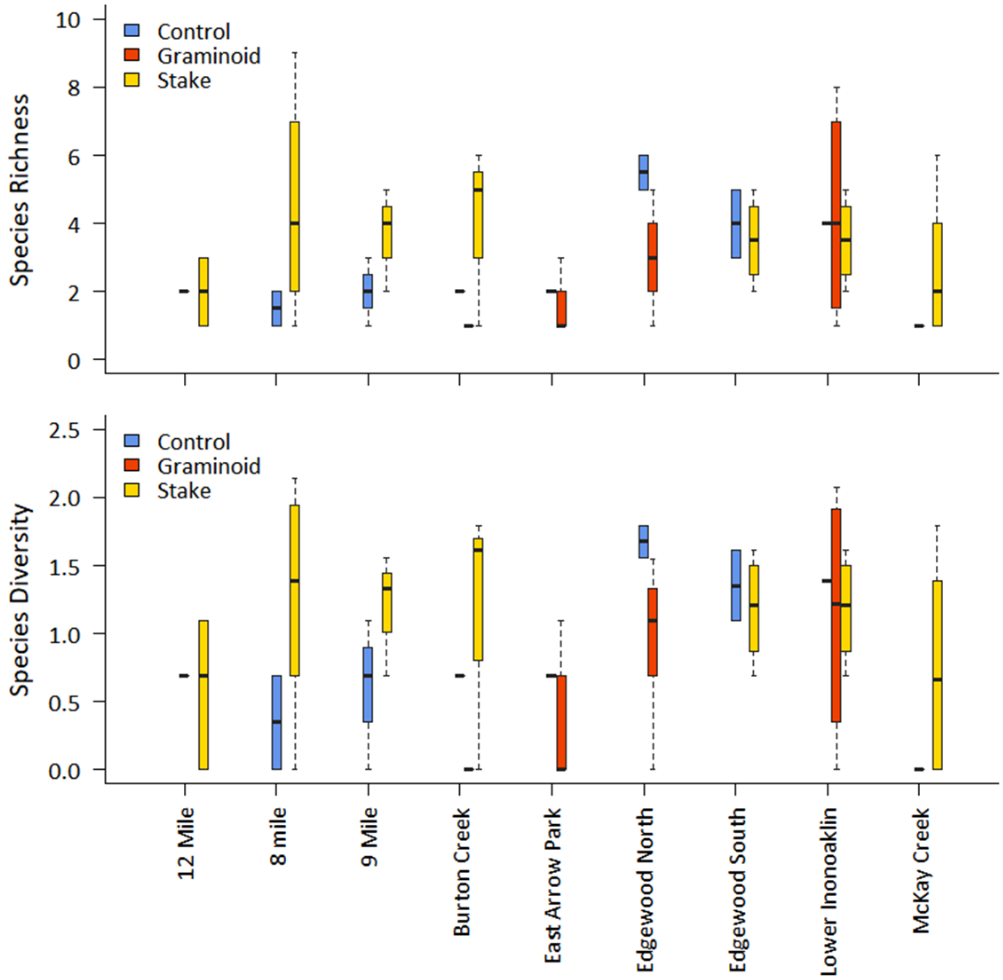

Figure 5-19: Boxplots showing bird species richness (top panel) and diversity (bottom panel) by habitat type (control [blue], graminoid sedge-plug [red], and live stake [gold]) at all study sites. Note that no surveying was conducted in 2012 and 2014.

As diversity accounts for species abundance, diversity values were all very low when comparing points within the reservoir inundation zone. Within the 30 m distance buffer used to assess revegetation effectiveness very few individual birds were detected, resulting in median diversity values being near zero for many stations. Trends are the same as those presented for species richness. Overall there was no difference in diversity across the habitat types (χ^2=4.16, df=2, p=0.13).

5.4.2 Songbird species composition and similarity

The 2018 point count bird community dataset consists of 49 species detected within 30 m of the point count centre. Out of these species, 20 were represented by only a single detection, and a further eight were only detected twice. Thus, it is not possible to reliably compute community analyses on these data. With caution in interpreting the trends expressed, an nMDS ordination showed no clustering by treatment (Figure 5-20). The control, graminoid and stake treatments showed non-assortative clustering, indicating similar songbird communities.

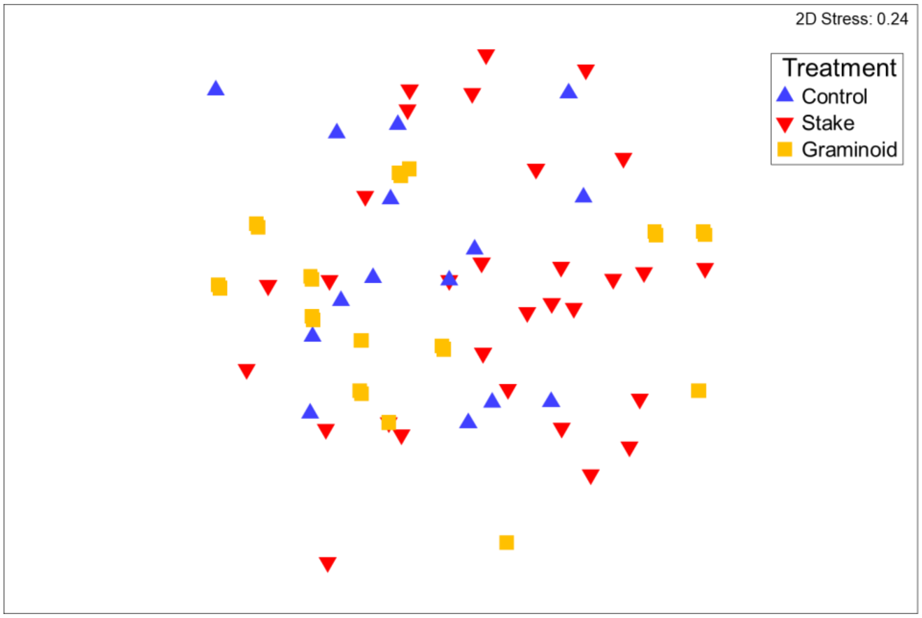

Figure 5-20: Non-metric multidimensional scaling (nMDS) plots showing the similarity among songbird point counts by treatment type based on their species composition. The 2D Stress value of >0.2 indicates that the plot does not necessarily represent the actual higher-dimensional trends.

The most frequently detected species within the constrained dataset (observations within 30 m) in the drawdown zone consisted mostly of aerial insectivores, hummingbirds, and shrub-associated songbirds such as warblers and flycatchers (Figure 5-21). Ground-nesting passerines, including Western Meadowlark (WEME) and Savannah Sparrow (SAVS) were relatively infrequently detected.

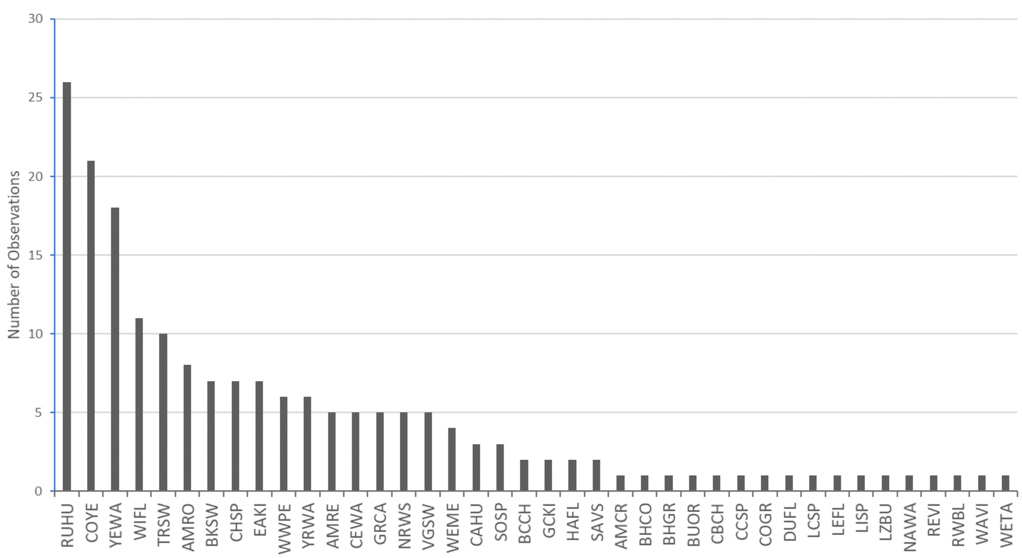

Figure 5-21: Number of observations of all songbird (and hummingbird) species detected within 30 m of point counts during 2018 surveys. Species codes presented in Appendix J.

In 2018, a total of two species of conservation concern were detected during point count surveys. These were Great Blue Heron (blue-listed provincially), and Bank

Swallow (listed as Threatened by the Committee on the Status of Endangered Wildlife in Canada and listed under Schedule 1 of the *Species at Risk Act*). Additional bird species of conservation concern have been noted in the drawdown zone in previous years (see Wood et al. 2018).

5.4.3 Nesting Evidence

In total, breeding evidence was found for 14 species from all sites where point counts and nest searches were conducted in 2018 (Table 5-3, Appendix K). A total of 40 nests were found (Table 5-3, Appendix K). Most nests were from either shrub-nesters (e.g., Cedar Waxwing, Willow Flycatcher), or ground-nesters (e.g., Spotted Sandpiper, Killdeer) The most frequently encountered was Cedar Waxwing (9 nests), with breeding evidence detected from four sites. Almost half of all discovered nests were from just two sites: McKay Creek, and Lower Inonoaklin. In total, 26 nests were discovered within non-revegetated areas. Out of the remaining 14 nests, one (Chipping Sparrow) was found within the proposed WPW location, one in a graminoid treatment (Killdeer), and 12 within the stake treatment. However, most of the nests within the stake treatment were not in planted vegetation. Shrub and tree-nesting species were found nesting within planted cottonwood stakes on three occasions in 2018 (American Robin, Cedar Waxwing and an unidentified nest).

The date that nests were found ranged from June 3rd to July 7th. There were eight documented nest failures and six probable nesting successes (Table 5-3). Out of the eight failures, inundation by rising reservoir levels was implicated in three, and may have been a contributing factor in at least two others. These three inundated nests were all from ground-nesting species (Killdeer, Spotted Sandpiper, and unidentified duck), and were from graminoid, stake, and control areas respectively.

Table 5-3: The nesting fates of the 40 nests located during 2018 by study site. Refer to Appendix K for additional nest details.

	Nest Fates				
Site	**Success**	**Probable**	**Failure**	**Unknown**	**Total**
McKay Creek	0	0	2	7	9
8 Mile	0	2	2	2	6
9 Mile	0	2	0	3	5
12 Mile	0	0	0	1	1
East Arrow	0	0	0	1	1
Burton Creek	0	0	0	4	4
Lower	0	2	1	7	10
Edgewood	0	0	2	1	3
Edgewood	0	0	1	0	1
Total	0	6	8	26	40

5.5 Wildlife Physical Works

Baseline data collection for certain groups (arthropods, songbirds, and bats) occurred in 2017 and 2018 and are summarized in this report and Wood et al. (2018). Additional data collected under CLBMON-37 indicate that two species of gartersnake (*Thamnophis sirtalis* and *T. elegans*) are abundant at the site. Western Toad (*Anaxyrus boreas*), Columbia Spotted Frog (*Rana luteiventris*) and Pacific Chorus Frog (*Psuedacris regilla*) use habitats in and adjacent to the proposed physical works locations (See results in CLBMON-37 annual reports).

The WPW site was characterized predominately by a graminoid vegetative cover (including reed canarygrass) (Figure 5-22). The average per cent of live organic matter in the WPW site ± SE was 25% ± 4.5% (n=5). The substrate was primarily composed of plant litter (93.8% ± 6%; n=5).

Figure 5-22. Malaise tent (top photo) and pitfall trap array (bottom photo) at the Wildlife Physical Works site. Photos taken during first collection period on June 9, 2018 in the Arrow Lakes Reservoir.

5.5.1 Arthropods

Average insect biomass ± SE was 4.82 ± 1.36 mg/hr for pitfall traps (n=8) in the WPW site. Insect biomass collected in Malaise traps was 6.93 mg/hr for the first collection and 19.85 mg/hr for the second collection. The average catch per unit effort for pitfall traps in the Wildlife Physical Works site was 55 individuals ± 15 (n=10).

We captured a total of 136 Hymenopterans comprising 26 families (Figure 5-23) and 10,051 Dipterans comprising 30 families (Figure 5-24) from Malaise traps located in the pre-treatment WPW site in Burton (n=2). We captured a total of 153 adult spiders and 441 immatures comprising 7 families and 18 known species (Figure 5-25). One individual spider was collected that is adventive to Canada (Lycosidae: *Trochosa ruricola*). We captured a total of 109 adult beetles comprising 11 families from pitfall traps located in the pre-treatment Wildlife Physical Works site in Burton (n=10) (Figure 5-26). In these samples there were 46 adult carabid beetles comprising 12 species (Figure 5-27). Three adventive carabid species were found at this site: *Pterostichus melanarius, Carabus granulatus,* and *Clivina fossor*.

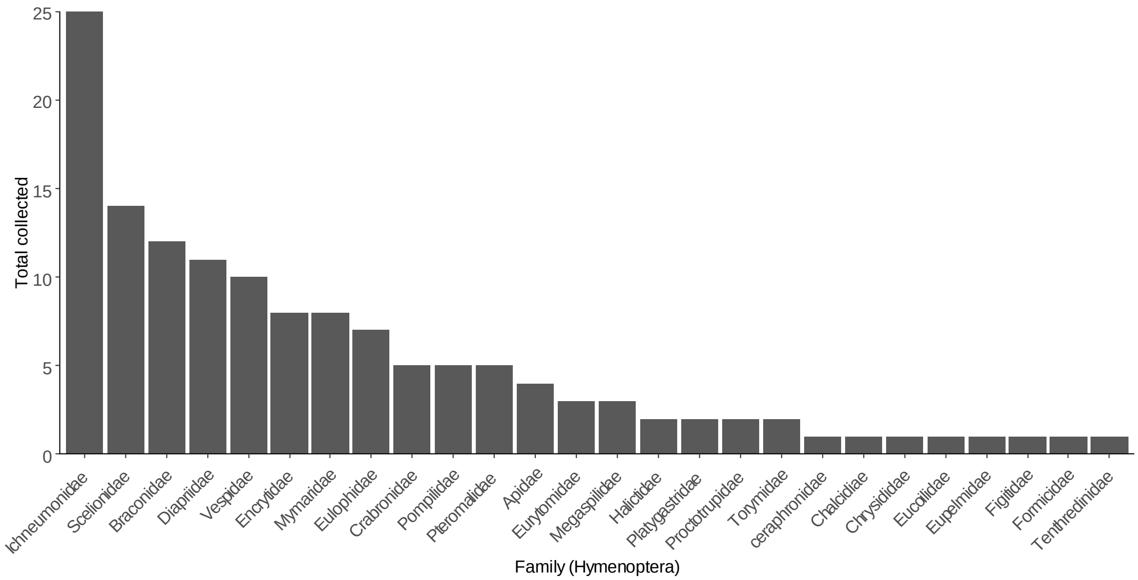

Figure 5-23. Hymenoptera families and associated abundances (not standardized to trapping effort) collected from Malaise traps in the pre-treatment Wildlife Physical Works site (n=2). Samples were collected along the Arrow Lakes Reservoir in 2018.

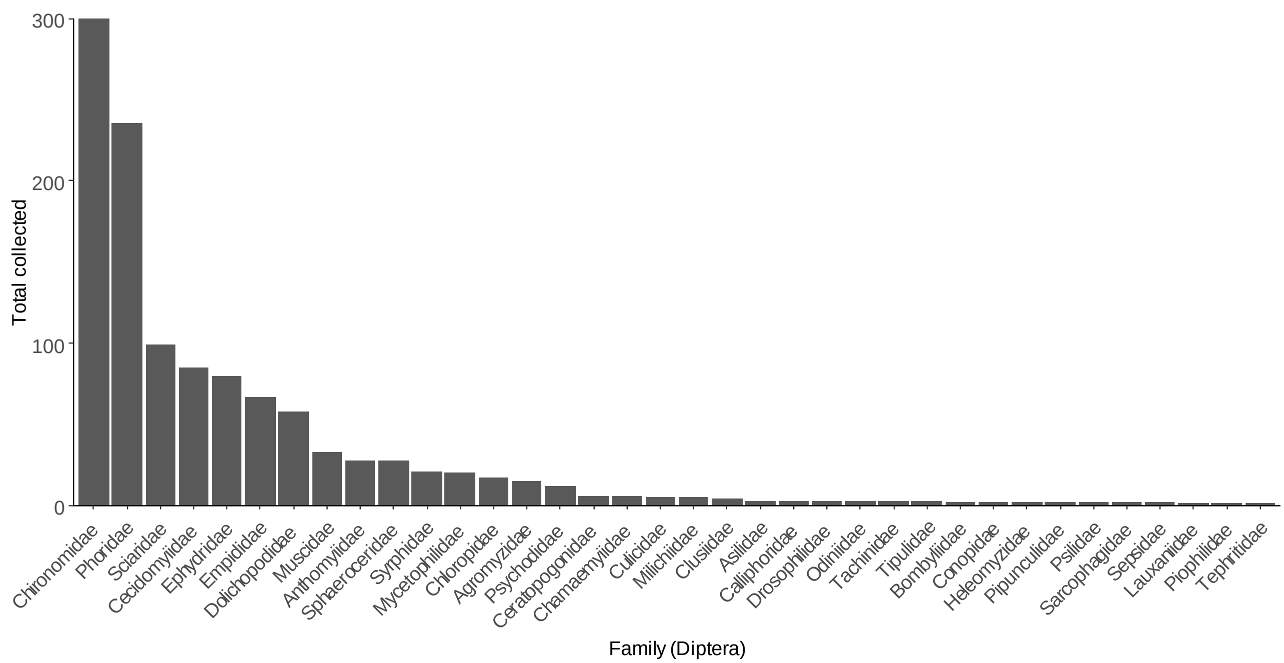

Figure 5-24. Diptera families and associated abundances (not standardized to trapping effort) collected from Malaise traps in the pre-treatment Wildlife Physical Works site (n=2). Abundance for Chironomidae (n=1291) exceeded graph cap of 300 individuals. Samples were collected along the Arrow Lakes Reservoir in 2018.

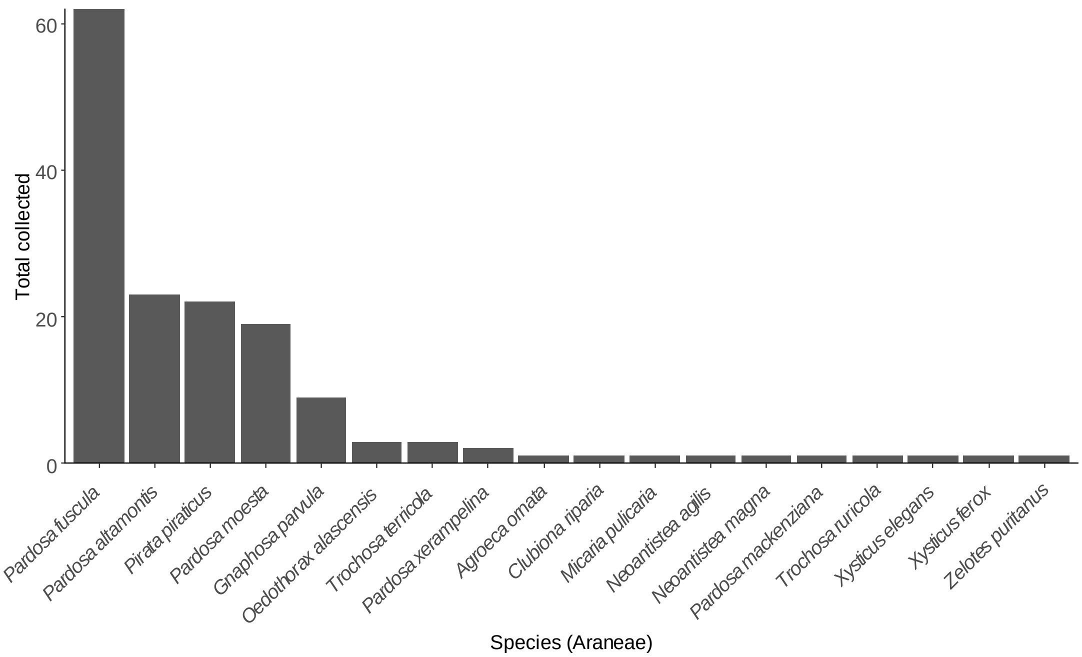

Figure 5-25. Araneae species and associated abundances (not standardized to trapping effort) collected from pitfall traps in the pre-treatment Wildlife Physical Works site (n=10). Samples were collected along the Arrow Lakes Reservoir in 2018.

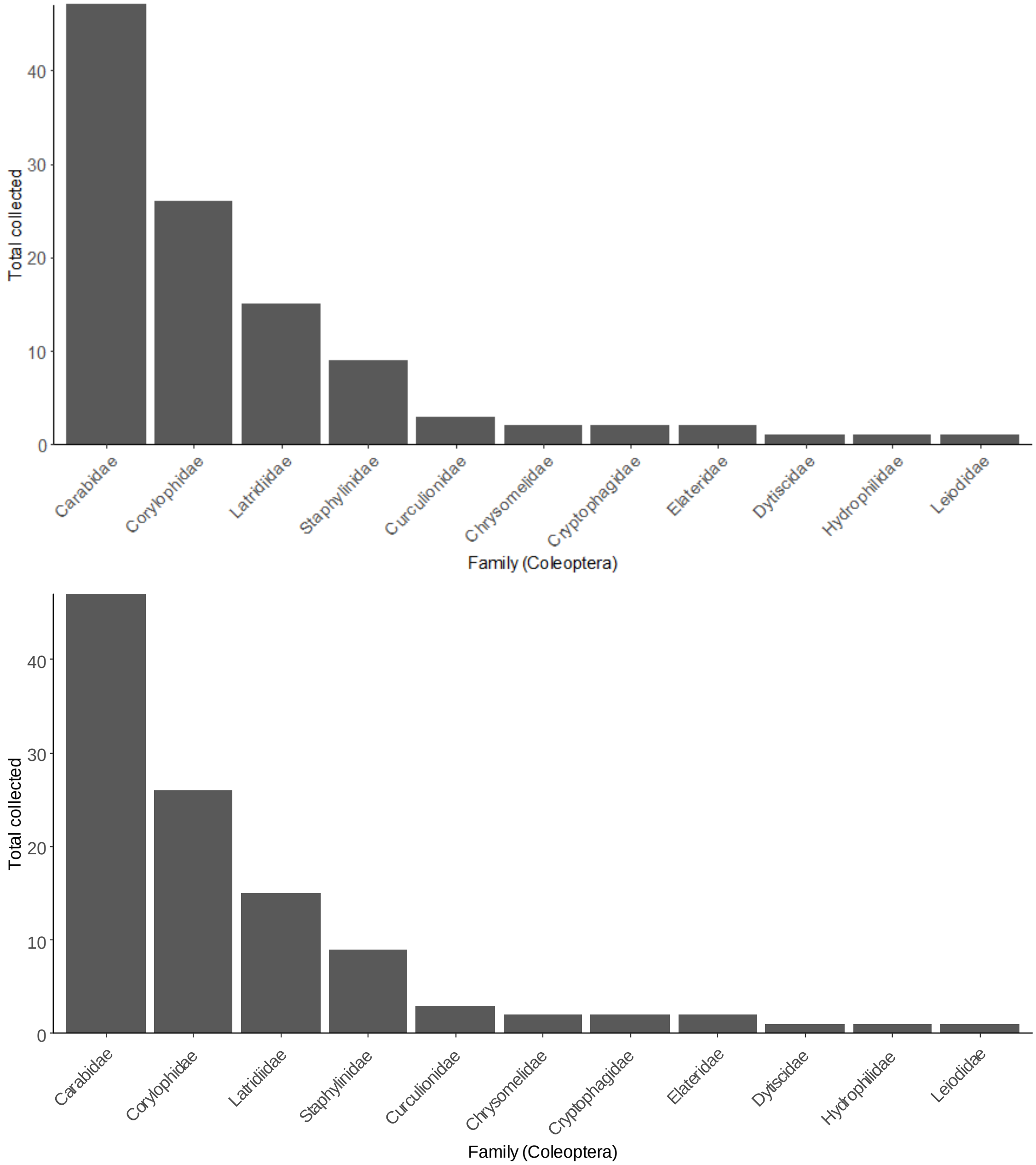

Figure 5-26. Coleoptera families and associated abundances (not standardized to trapping effort) collected from pitfall traps in the pre-treatment Wildlife Physical Works site (n=10). Samples were collected along the Arrow Lakes Reservoir in 2018.

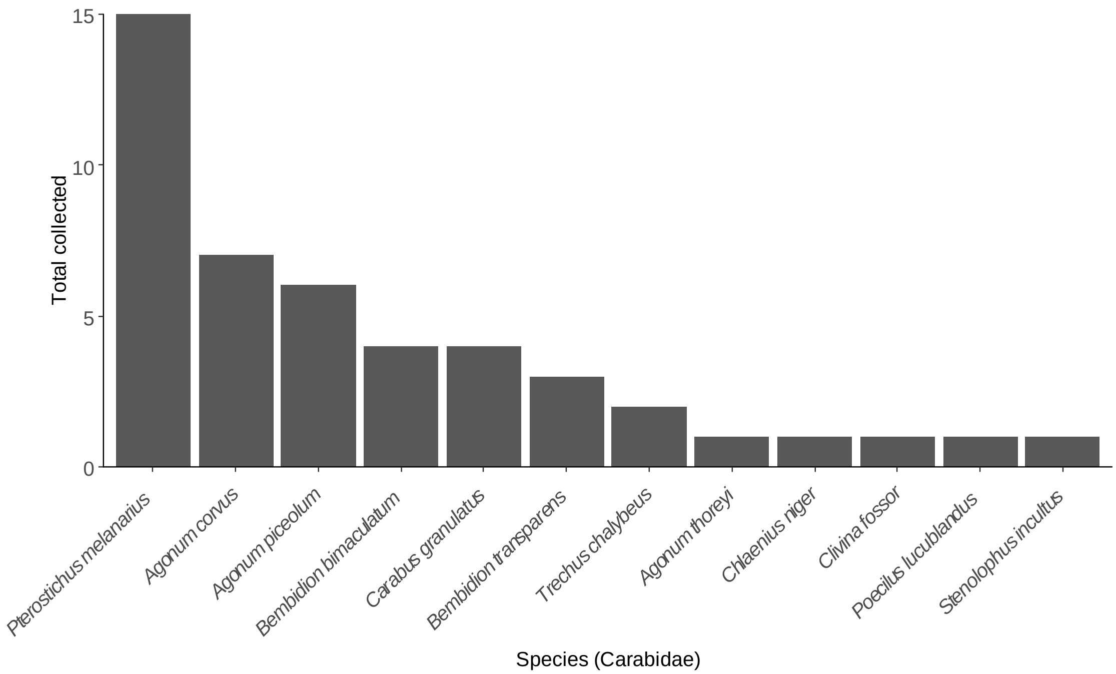

Figure 5-27. Species and abundances of carabid beetles (not standardized to trapping effort) collected from pitfall traps in the pre-treatment Wildlife Physical Works site (n=10). Samples were collected along the Arrow Lakes Reservoir in 2018.

5.5.2 Birds

Fourteen observations of six bird species were recorded within 30 m of the point count centre from the five point count locations in the WPW area during summer 2018: American Robin, Common Yellowthroat, Dusky Flycatcher, Lazuli Bunting, Rufous Hummingbird, and Yellow Warbler. Several of these were detected from the forest edge, such as the Dusky Flycatcher and Lazuli Bunting. Both the Common Yellowthroat and Yellow Warbler are marsh and riparian species.

In total, 92 bird species were recorded during spring through autumn waterbird surveys. Within the proposed physical works location, there were four species recorded during the spring survey: American Crow, Common Yellowthroat, Belted Kingfisher, and 6 Mallard. In August, sightings within the physical works location included Great Blue Heron, Killdeer, Bald Eagle, and for waterfowl, Common Merganser and Canada Goose. In September the only detection within the wildlife physical works location was 175 Canada Goose (Appendix L).

5.5.3 Bats

All 11 species of bat were detected by autonomous recording units from the wildlife physical works area. These were predominantly species of *Myotis*, especially Little Brown Myotis (*Myotis lucifugus*). The detectors at Burton Creek had the lowest bat detection rates compared to other sites. Of these, BUWPWP02 recorded the fewest calls (2.46 calls per detector-hour; Figure 9-1). The general proportion of detections per species consistent between 2017 and 2018 (Figure 5-28). However, we noted a large amount of within site (between-detector) variation, which could not be explained (e.g., differences between the three Burton WPW detectors).

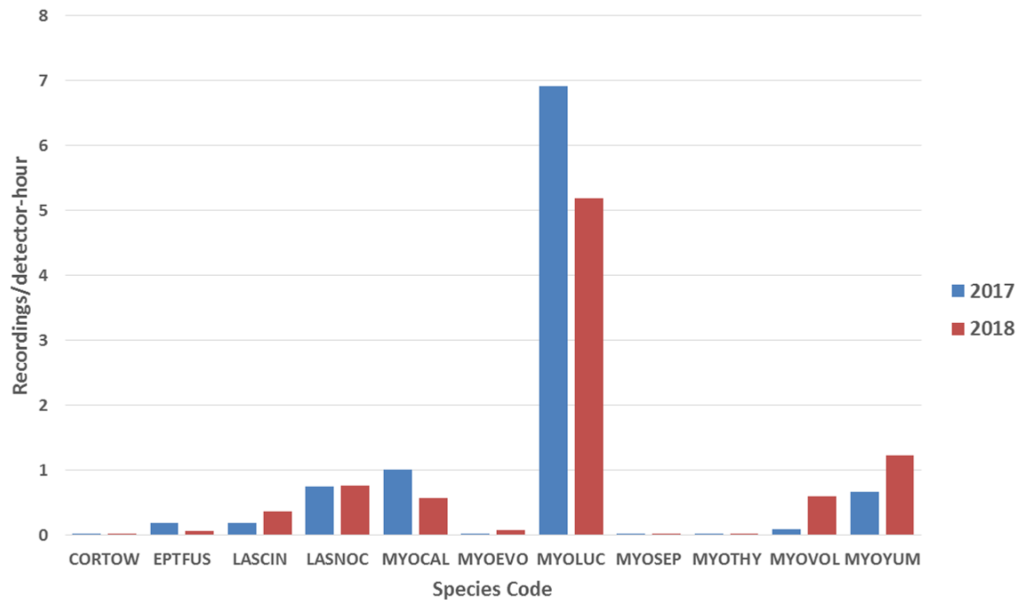

Figure 5-28: Proportion of recordings per detector hour for all bat species recorded from Burton Creek Wildlife Physical Works area located autonomous recording units in 2017 and 2018.

6.0 DISCUSSION

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

6.1 Revegetation

Results of wildlife effectiveness monitoring to date has failed to detect any clear overall effect of revegetation prescriptions. There is little indication from annual results that revegetation treatments are effective at enhancing wildlife habitat.

If vegetation cover and/or structure are different for treatment areas than adjacent controls, arthropod responses are expected to differ. This is due to the high degree of specificity to habitat quality exhibited by terrestrial arthropods. For both ground-dwelling spiders and beetles, vegetation cover increases relative humidity of the soil surface, which provides favourable conditions for many species. Additionally, beetle species (e.g., Carabidae and Staphylinidae) that develop in the upper layers of soil during their larval stages, are highly selective to soil substrate composition, relative humidity, and in some cases salinity and pH of the soil. Spider species are strongly tied to changes in vegetation structure, as this provides different niches for spiders that specialize in different modes of prey capture. Sites with bare ground are usually dominated by spiders that do not require webs for prey capture (e.g., Wolf spiders, Crab spiders). Sites with low herbs such as sedges/grasses may provide a niche for the funnel-web building spiders and for species with lower tolerance to dry sites. Higher vegetation provided by willows/shrubs provides habitat for web-building spiders of various species. Forested habitats provide numerous additional niches not provided by open habitats.

Within the drawdown zone control and treatment areas, arthropod biomass, relative abundance, and diversity were similar and consistent with the results of previous annual reports. An exception was an increase in carabid beetle diversity in graminoid polygons (compared to control polygons), and trends for increased carabid CPUE in revegetated polygons at some sites (both stake and graminoid). Species composition differences for ground beetles and spiders suggested an interaction between site and treatment type, although there was no clear effect of stake versus graminoid treatment. There seems to be mixed responses to revegetation by arthropods, but no clear, consistent trend. For the most part, treatment and control areas largely seem to function similarly in providing habitat for arthropods.

One limiting factor this sampling period was the lack of replication of treatment type within and between some sites due to high reservoir levels. This was especially true for graminoid revegetation polygons. Future years of monitoring are needed to better assess a range of revegetation polygons within the study sites and their effect on the arthropod community.

Songbirds are also expected to respond to changes in vegetation structure, for example, through their nest site selection. Areas containing stake and graminoid vegetation are likely to provide habitat for bird species that is not available in adjacent drawdown zone areas with bare ground. However, songbird point count data has failed to detect a clear effect of revegetation treatments in comparison with adjacent drawdown zone controls. The number of bird detections is consistently low in treatment and control habitats, while variance is often high. Richness, diversity, and composition patterns provide no consistent trend towards treatment effects.

Nest data provides useful supplementary data on the presence of bird nesting habitat. Reservoir impacts on nesting birds has been the focus of CLBMON-36 (e.g., Craig et al. 2018). While not a main focus of CLBMON-11B1, nest surveys provide information on nesting habitat suitability. For example, the presence of songbird nests in planted cottonwoods is evidence that at least some birds will utilize transplanted vegetation for nesting where suitable characteristics exist. Furthermore, additional species may find suitable foraging habitat within the drawdown zone, even when suitable nesting habitat does not exist.

Our ability to detect an effect may be constrained by the experimental design of the CLBWORKS-2 revegetation program and the variable levels of vegetation establishment. The CLBWORKS-2 revegetation program treated approximately 106 ha of drawdown zone habitat from 2008-2011. Revegetation efforts achieved mixed success at promoting vegetation establishment. Results from CLBMON-12 monitoring found some polygons had nil survival of plantings, while others appeared vigorous and thriving. The only significant differences in vegetation cover were found for the upper elevation band in the “redtop-upland” vegetation community type (438-440 m ASL), which had greater shrub cover than adjacent controls (Miller et al. 2018). Thus, our inability to detect a difference between treatment and control areas may be explained by these vegetation results.

However, revegetation success was noted by Miller et al. (2018) at several of the selected polygons monitored for CLBMON-11B1 in 2018 (Lower Inonoaklin: 2009_18, 2011_23; Edgewood South: 2009_3; 12 Mile: 2009_87; and 9 Mile: 2010_RR).

It should be noted that several other factors related to the original revegetation program may confound our results. For example, planting in revegetation treatment plots was sometimes applied to areas with poor growing conditions relative to non-treatment areas within the same site, resulting in a potential underestimation of revegetation effectiveness (Enns and Overholt 2013). Revegetation was not applied in a manner that accounted for the scale at which many organisms would utilize the drawdown zone (i.e., revegetation polygon size was smaller than the home range or territory size of many animals). Beyond inherent differences between treatment and control areas, our ability to detect any true changes are limited by within-site, among-site and among-year differences, small samples sizes (owing to a limited number of treatment polygons per site), and a lack of revegetation success.

6.2 Wildlife Physical Works

As stated in Hawkes and Tuttle (2016), wildlife habitat suitability at the Burton Creek Wildlife Physical Works location is low for most species groups considered (e.g., arthropods, songbirds and waterfowl). The species richness of bats is as expected (n=11 species), but relative to other areas monitored in and adjacent to Arrow Lakes Reservoir, detection rates are currently low (Table 9-3). The proposed physical works project at Burton Creek is anticipated to improve habitat suitability for wildlife including birds, amphibians, reptiles (Burton Flats currently has high suitability for snakes – this is not expected to change), mammals (bats), insects (dragonflies) and fish (among others). Species with provincial or federal conservation designation that will benefit from this project include the provincially blue-listed and COSEWIC species of Special Concern, Western Toad (*Anaxyrus boreas*); the provincially blue-listed Townsend's Big-eared Bat (*Corynorhinus townsendii*) and Fringed Myotis (*Myotis thysanodes*); and the COSEWIC endangered Little Brown Myotis (*Myotis lucifugus*) (listed February 27, 2012).

Monitoring at Burton Creek in 2018 (and in previous years) will provide the data necessary to assess the effectives of the proposed physical works to provide habitat for wildlife. The data collected to date will provide a suitable baseline for those future comparisons.

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

1. Creation of at least new wetland habitat in an area dominated by grasses (i.e., no current wetland habitat – see Section 4.2).
    a. Temporal availability of wetland overlaps with the migratory bird (particularly wetland-associated species) and amphibian breeding seasons (May-August). The permanence of the wetland should be assessed (i.e., is the wetland available each year and for how long?)

b. Minimum depth of pond required to support amphibian breeding and larval development (See Section 4.2).

2. Wetland productivity.

a. Successful establishment of native macrophytes (planted or natural) into newly created wetlands within five years. “Successful establishment” is defined here as continuous species presence for at least two years. Currently there are no macrophytes at the site proposed for physical works.

b. Successful natural establishment of native macroinvertebrates (e.g., odonates, cladocerans, gastropods) into newly created wetlands within 5 years. “Successful establishment” is defined here as continuous species presence for at least two years. The current biomass of macroinvertebrates at this site is nil.

c. Evidence of breeding by amphibians (specifically Western Toad). The number of egg strings or masses should be counted on an annual basis following the implementation of the physical works. Egg development should be tracked to determine if eggs metamorphose into froglets or toadlets. Western Toads currently breed in the ponds situated at elevations <434 m ALS, but do not breed at the site proposed for physical works.

d. Evidence of use of the wetland by waterfowl and shorebirds. Waterfowl have been observed using the area proposed for physical works, but only in small numbers, especially when inundated by Arrow Lakes Reservoir.

e. Evidence of use of habitat enhancements (e.g., nest boxes, floating islands) by target waterfowl species (which will need to be determined) following completion of construction.

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

6.3 Management Questions

Management questions as presented in the 2009 Terms of Reference were addressed in previous annual reports (e.g., Wood et al. 2018). This report marks the first under the revised Terms of Reference (BC Hydro 2017). This project thus spans two main components addressed in five overarching management questions. The first component deals with the legacy study of assessing revegetated and control (not revegetated) areas of the drawdown zone, to quantify the efficacy of those revegetation prescriptions. The second component deals with the proposed creation of a wildlife physical works project, and associated wildlife response. Many of the initial challenges in answering questions related to the first component remain, as they are ecological problems arising from a spatial mismatch between the small size of revegetation polygons and the larger home range size of many organisms within the drawdown zone (e.g., bird territories). Questions related to the wildlife physical works can not yet be answered, as 2018 represented a year of baseline data collection prior to the physical works being constructed.

Each Management Question is individually addressed below.

6.3.1 MQ-1: Were the revegetation projects effective at increasing wildlife utilization or enhancing the suitability of wildlife habitat to a biologically meaningful extent?

a. *How did the revegetation projects affect the productivity (measures of biomass, or reproductive success) of wildlife habitat in the drawdown zone?*

To date, CLBMON-11B1 has provided little evidence suggesting that revegetation prescriptions were effective at enhancing productivity of wildlife habitat in the drawdown zone. Productivity has been monitored by arthropod biomass and by avian productivity measures.

The biomass of arthropods is a key response variable currently used as a measure of habitat productivity. There has been no clear trend to support increased arthropod biomass in the drawdown zone due to the revegetation prescriptions.

The clearest evidence of increased productivity is the observation of a few birds nesting in revegetation treatments, notably in cottonwood plantings. Nesting productivity may thus have increased for a few species or individuals relative to the pre-revegetated state. However, this is limited and site-specific. Evidence of bird nesting in planted vegetation exists mainly at Lower Inonoaklin, where Black Cottonwood plantings have been highly successful relative to other sites.

b. *What were the conditions at the revegetation study sites in terms of wildlife habitat suitability at the time of project initiation?*

A lack of baseline sampling before revegetation treatments were implemented prevents analysis of wildlife habitat suitability at the time of project initiation. Based on the general lack of revegetation success in many areas, and the lack of difference observed between revegetated and untreated areas recently, it is believed that habitat suitability is likely similar overall now compared to project initiation. In some specific cases wildlife habitat suitability has likely been increased. Most notably this is true at Lower Inonoaklin, where planted cottonwood stakes have been successful. At this location there is evidence that increased nesting and foraging opportunities for shrub-nesting species occur relative to baseline conditions.

c. *How did revegetation modify the area (m^2) or the suitability of wildlife habitat based on: comparisons between treated and untreated areas, vegetation change over the course of the monitoring study, and available baseline data on vegetation structure?*

Revegetation efforts were assessed in 2017 and were reported to have achieved mixed success (see Miller et al. 2018 for more detail). Areas containing successfully revegetated stakes and graminoid cover are likely to provide some additional habitat for certain bird species that is not available in drawdown zone areas with bare ground. Indeed, several species have been observed breeding and foraging within revegetated areas (notably cottonwood stakes) (see Section 5.4.3 Nesting Evidence). Likewise, arthropod species are highly sensitive to changes in vegetation structure and vegetation density, thus are expected to respond to revegetation areas. On a basic level there is evidence of some enhancement to wildlife habitat, but it is very limited. Most results failed to detect differences between revegetation prescription treatments and adjacent control areas. Thus, overall there is no strong evidence that revegetation increased the suitability of wildlife habitat. Our ability to detect wildlife responses may be hindered by various factors related to the study design of revegetation work: 1) the size of the revegetation treatments and their proximity to adjacent habitat may obscure patterns in wildlife use; 2) the type of revegetation prescription (e.g., live stake vs. plug seedling) may not be preferred habitat; 3) the lack of replication at the treatment level makes it difficult to detect a signal, even if one exists; 4) variability in administration and success/survival of revegetation treatments; and 5) pre-treatment within-site, and among-site variation obscures overall trends in wildlife habitat use.

d. Did revegetation affect songbird utilization of habitat as measured by species richness and/or relative abundance, based on: comparisons between revegetated and untreated areas, and/or vegetation change over the course of the monitoring study?

There is limited evidence that revegetation has affected songbird utilization compared to untreated areas. In terms of species richness and diversity there are no clear trends, and treatment was not a significant factor. As discussed previously there may be some site-specific cases where revegetation has increased songbird utilization, and this is most apparent in the cottonwood stake treatment at Lower Inonoaklin. This was the only site where nesting evidence could directly be related to revegetation. Overall songbirds are not an informative indicator for monitoring revegetation change in this study due to significant data and ecological constraints resulting from the scale of revegetation prescriptions. Many songbirds have breeding territories which are much larger than the size of revegetation patches. This small revegetation polygon size also forces point count data to be constrained to a 30 m radius (as beyond, and sometimes even within, that distance, a different revegetation area or untreated section occurs. This distance is not wholly appropriate for point count data, and results in a low number of data points as few birds are recorded within those close distance bands in open habitats. This severely restricts quantitative assessment of the bird data.

e. Did revegetation affect bat utilization of habitat as measured by relative activity levels and estimated species richness recorded by remote acoustic detectors, based on: comparisons between revegetated and untreated areas, and/or vegetation change over the course of the monitoring study?

Due to the small size and proximal distribution of treatment and control plots within a site, it is not possible to compare bat activity between the revegetated and untreated areas of the drawdown zone in a biologically meaningful manner. Bats occupy ranges larger than the prescribed revegetation polygons and can fly over large areas while foraging. We can determine that bats, of multiple species, are utilizing all our study areas, and this likely includes both revegetated and untreated areas. However, it is not possible to make comparisons between these habitat types.

f. Did revegetation affect terrestrial arthropod abundance (e.g., biomass, catch per unit effort, etc.) and species richness, based on: comparisons between revegetated and untreated areas, and/or vegetation change over the course of the monitoring study?

If vegetation treatment was effective at producing habitat of a higher quality than control plots, we would expect an overall higher arthropod biomass and CPUE at treatment plots. We would also expect a higher diversity and richness of terrestrial arthropods. Quality vegetation can offer better habitat and resources for arthropods; increased vegetation structure and diversity can positively influence terrestrial arthropod abundance and diversity (Humphrey et al. 1999; Söderström et al. 2001). Depending on the habitat the treatment type offered, we would expect to see some shifts in species composition based on species life history.

As reported for management question 1a, revegetation treatment (stake or graminoid) had no consistent effect on arthropod biomass relative to non-revegetated polygons. Similarly, there was no obvious overall effect of treatment type on arthropod CPUE. This suggests no clear influence of revegetation treatments on the arthropod community.

Responses of families within three arthropod orders (Hymenoptera, Diptera, and Coleoptera) showed no strong effect of revegetation. While Coleopteran diversity was higher in controls relative to stake polygons at two sites (9 Mile and 12 Mile), this effect was not consistent with trends in other sites. Overall, there was no obvious affect of revegetation on diversity or rarefied richness for Coleopterans. There were no clear patterns on whether treatment influenced the dominant Hymenopteran and Dipteran families in each area, although supporting data for these families were limited.

Although spider species (Araneae) showed at best a mixed response to revegetation that varied site-by-site, trends for carabid beetles (Coleoptera: Carabidae) were more positive in response to revegetation (particularly graminoid revegetation). At most sites spider diversity, richness, and abundance were not different between revegetated and control polygons. What trends did appear were more likely to be negative, but not consistently so, and did not seem specific to revegetation type. Conversely, carabid diversity seemed to increase in graminoid polygons at multiple sites. Herbivorous or omnivorous carabid beetles may benefit from food resources (such as grass and sedge seeds) offered by graminoid revegetation plots. Trends in carabid abundance were less clear, but two sites did show increased carabid abundance in graminoid or stake revegetation polygons relative to control polygons.

Of the measures of arthropod abundance, diversity, and richness that we considered, only carabid beetles showed a particularly notable (positive) response to one type of revegetation treatment (graminoid). The mixed response of other arthropod groups precludes any strong inference being made about the effects of revegetation.

We found that spider and ground beetle species composition was influenced by the interaction of study site and revegetation treatment (see Composition results). While control sites appeared to house distinct species assemblages from treated polygons, the variance explained by RDAs was relatively low, and cover of LOM was not significantly ($p>0.1$) associated with species composition. Thus, results suggest that the relationship between species assemblages and polygons may not be related to vegetation cover. Extraneous factors may account for the differences between control and treatment polygons. For instance, within each site, the available area for selecting control samples was constrained by reservoir elevations, and may have differed slightly in elevation, topography, or other small-scale differences that altered the species composition locally. Patterns in species composition may become clearer as more species-level data is collected and with increased sampling across revegetation polygons within each site.

We did see some evidence of site-by-site differences in treatment effects. While some environmental noise can be expected in field studies such as these, there may be larger, unaccounted for affects of site (such as location relative to other sites, heterogeneity of reservoir effects between sites, or larger-scale habitat characteristics) that are causing these differences. High reservoir levels also made it difficult to get replication of each treatment type in every site, which limits the effectiveness of within-site comparison. While we placed ‘stake’ and ‘graminoid’ into categories to allow for analysis, the variety of implementation methods even within a treatment type (such as depth of planting, method of hand or machine planting, or vegetation species) makes it difficult to control within-treatment variation between sites. Finally, the lack of pre-treatment baseline data makes it difficult to understand how successful the revegetation treatments actually are.

g. Did revegetation affect ungulate utilization of habitat as measured by indices of use (e.g. pellet counts, tracks and occupancy), based on: comparisons between revegetated and untreated areas, and/or vegetation change over the course of the monitoring study?

Ungulate data was only collected incidentally for CLBMON-11B1 in 2018. As mentioned previously, the scale of revegetation application does not necessarily correspond to the home range size of ungulate species, which range broadly. A total of 22 observations of ungulate were recorded in 2018 from seven sites ranging from McKay Creek in the north to Edgewood North in the south. All observations were of deer sp. (White-tailed and Mule Deer could not be differentiated based on tracks/scat), except for single observations of sign of Elk and Moose. There were 10 observations each of tracks and scat, and no live animals were witnessed in any of the sites. Observations were evenly split between control (untreated) and revegetated areas. There is thus no evidence suggesting that revegetation affects ungulate utilization, either positively or negatively. However, the results show that ungulates do not avoid revegetated areas and utilize treated areas at least for passage.

6.3.2 MQ-2: Were the wildlife physical works projects effective at increasing wildlife utilization or enhancing the suitability of wildlife habitat to a biologically meaningful extent?

a. How did the wildlife physical works projects affect the productivity of aquatic or terrestrial wildlife habitat in the treated drawdown zone sites?

Development of potential wildlife physical works (WPW) are ongoing. Projects have been identified (Hawkes and Tuttle 2016) but were not yet implemented prior to 2018 sampling. WPW is scheduled for Burton Creek, where two seasons of pre-WPW sampling has been conducted to serve as a baseline for future monitoring. Having wildlife usage well documented prior to implementation of physical works provides a powerful assessment of before-after effects on a case by case basis. Additional data collection of the WPW are scheduled in accordance with the revised Terms of Reference (BC Hydro 2017). It is expected, however, that physical works which create wetland habitat in the drawdown zone have a high potential to increase productivity.

b. *What were the baseline conditions at the wildlife physical works study sites in terms of aquatic and terrestrial wildlife habitat productivity and habitat quality?*

Previous research into habitat suitability in the Burton Wildlife Physical Works study site suggests that suitability is relatively low for species such as arthropods, songbirds, and waterfowl (Hawkes and Tuttle 2016).

We identified 26 families of Hymenoptera, 30 families of Diptera, seven families and 18 species of Araneae, 11 families of Coleoptera, and 12 species of Carabidae in the Burton Wildlife Physical Works (WPW) study site. We also established baselines for arthropod biomass and CPUE. This area was notable for containing non-native arthropod species. Though no adventive spiders were collected in any other traps throughout the Arrow Lakes sampling, one adventive spider species (*Trochosa ruricola*) was collected at the Burton Creek WPW site. This species was not collected previously in our sampling of the Arrow Lakes Reservoir. In addition, three adventive Carabidae species (*Pterostichus melanarius, Carabus granulatus,* and *Clivina fossor*) were collected at the Burton Creek WPW site. Unfortunately, *P. melanarius* was the most common ground beetle species at the WPW site, with 15 individuals. This species has been shown to rapidly expand in disturbed/human altered habitats, outcompeting native species of *Pterostichus*, which further supports the low habitat suitability of this area pre-treatment. While we would not expect the introduced species to decrease post-treatment, we would expect that the increased habitat heterogeneity will increase recruitment of a wider variety of ground-dwelling arthropod species, translating to increased species richness or diversity.

While the physical works area currently has low use by birds, both in the breeding season and migration, there appears to be a general trend in the area for a greater number of observations, and for observations to comprise a greater number of individuals, during fall. This may be due in part to the onset of kokanee salmon (*Oncorhynchus nerka*) spawning, as gulls, eagles, and ducks all were recorded from the Burton Creek area east of the highway. In general, waterfowl use of the proposed physical works location is limited to the periods when it is inundated by the reservoir. Adding water to the site results in the use of shallow areas by waterfowl. For example, in 2016 Gadwall (*Anas strepera*), American Wigeon (*Anas americana*), and Mallards (*Anas platyrhynchos)* were observed in the shallow margins of the reservoir. Similar species were observed in 2017, but not in the physical works, mainly as a result of reservoir elevations. Other bird usage is currently fairly low for the WPW area but includes both marsh and riparian breeding-species such as Yellow Warbler and Common Yellowthroat. Prescriptions focused on increasing avian productivity may best focus on wetland-breeding species which currently occur in low numbers in the area. In addition, prescriptions may have different temporal effects depending on bird species; for example, waterfowl usage may increase greatest during the fall.

c. *How did wildlife physical works projects change the area (m^2) or increase the suitability of habitat for wildlife?*

The wildlife physical works project has not yet occurred, and so we have no metrics on area or habitat suitability changes. Such investigations will be the focus of future years of surveying. Based on the results of baseline conditions to date, habitat suitability is expected to increase for wetland-breeding bird species, and waterfowl. Regarding waterfowl, change may be best monitored by continuing to survey across spring, summer and fall seasons.

d. *Did wildlife physical works projects change the utilization of the drawdown zone by birds as a measured by species richness, abundance and nest productivity?*

This question is not yet answerable as WPW have not been implemented. Based on baseline conditions to date, we expect that species abundance and nesting productivity will increase, as both are currently at low levels. Richness will likely also increase for the specific location of the WPW but will likely remain the same compared to the Burton Creek area as a whole. Nest productivity is expected to increase for waterfowl, and wetland and riparian-breeding bird species. However, the exact increase and species involved will ultimately depend on the vegetation component surrounding the wildlife physical works, such as the presence of shrubs or trees (e.g., cottonwood).

e. *Did wildlife physical works projects change the utilization of the drawdown zone by bats as measured by relative activity levels and estimated species richness recorded by remote acoustic detectors?*

We cannot currently address this question because the wildlife physical work projects have not yet taken place. This year's relative activity levels and species richness estimates represent essential baseline data to which post-physical works project monitoring will be compared. Bat detectors placed in Burton Creek (site of planned WPW) in 2018 reveal relatively low levels of bat activity compared to other sites (namely Lower Inonoaklin), but similar activity levels and species composition to off-reservoir reference area Armstrong Lake.

f. *Did wildlife physical works projects change the abundance (e.g., biomass, catch per unit effort, etc.) and species richness of arthropods in the drawdown zone?*

We cannot currently answer this question because the wildlife physical work projects have not yet taken place. Improvements to the wildlife physical works site that result in vegetation and substrate alterations will likely result in changes to arthropod species composition and abundance.

6.3.3 MQ-3: Did the revegetation methods result in changes to wildlife habitat for songbirds or bats as measured by indices of habitat suitability and site productivity (e.g., arthropod biomass, catch per unit effort, etc.), based on comparisons between revegetated and untreated areas, and of revegetated areas over the course of the monitoring study?

Revegetation methods did not result in changes to site productivity as measured by arthropod biomass (see Management Question 1a for more detail). Revegetation also had no overall effect on arthropod CPUE (see Management

Question 1f). While we cannot comment on prescribed treatment and control plot utilization by bats (due to reasons explained in MQ-2a.), arthropod biomass did not differ significantly across revegetated and untreated sampling areas in 2018. Scaling must be central to any questions regarding habitat utilization by aerial predators. Similarly there is no strong evidence that revegetation methods resulted in overall changes to songbird habitat with some exceptions. Notably the cottonwood stake treatment at Lower Inonoaklin appears successful, and both increased nesting and foraging opportunities for shrub-nesting species have been noted there. Overall the stake treatment appears more successful at creating songbird habitat within the drawdown zone at Arrow Lakes than the graminoid treatment. In most cases no difference exists between revegetated and untreated areas of the drawdown zone to songbird species richness and diversity.

6.3.4 MQ-4: Did the methods used for wildlife physical works result in changes to wildlife habitat for songbirds and bats as measured by indices of habitat suitability and site productivity (e.g. arthropod biomass)?

We cannot currently address this question because the wildlife physical work projects have not yet taken place. This year's relative activity levels and species richness estimates represent essential baseline data to which post-physical works project monitoring will be compared. We can predict that creation of appropriate aquatic habitat and subsequent vegetation establishment will support varied flying arthropod populations (bat food source), potentially resulting in increased bat activity. This may also influence songbird distribution or productivity. Habitat suitability will depend not only on the physical works, but on vegetation structure adjacent to the WPW location. It is predicted that the wildlife physical works will increase habitat suitability bot for songbirds and waterfowl.

6.3.5 MQ-5: Which revegetation or wildlife physical works methods or techniques (including methods or techniques not yet implemented) are likely to be most effective at enhancing or protecting the productivity of wildlife habitat in the drawdown zone?

It has been challenging to assess with monitoring data whether live-staking or plug seedling prescriptions were more effective at enhancing wildlife habitat in the drawdown zone. The ability to monitor the efficacy of these treatments has been hampered by the relatively small number of areas treated in the drawdown zone, the inconsistency/variability in treatment applications, the size of the areas treated, the lack of replication associated with each of the component revegetation prescriptions, annual variability in conditions (reservoir-related and otherwise), considerable natural variability within and among sites, and the lack of success and low survivorship of revegetation treatments. These factors have limited the use of inferential statistics to determine whether some methods are more effective than others. Initial site selection could not consider plant survival, and initial monitoring has instead documented habitat suitability at relatively few sites, in detail, over time. However, the data have shown that birds and arthropods do use revegetated areas, even if that usage does not differ from control areas. In particular, the successful planting of cottonwood stakes appears to provide opportunities for shrub-nesting birds. Productivity may be increased in these cases by providing a substrate for nests directly, or by increasing foraging opportunities within the drawdown zone. However, another study in the Arrow Lakes Reservoir (CLBMON-36) has shown that ground-nests and nests low in shrubs are particularly susceptible to inundation by rising reservoir levels, and that juvenile survivorship is affected by reservoir conditions (Craig et al. 2018). Thus, the provision of nesting substrate within the drawdown zone does carry some risk due to flooding, but that will vary by elevation, adjacent habitats, and species.

Unlike the revegetation program under CLBWORKS-2, the proposed Wildlife Physical Works for the Burton Creek site is being designed specifically with wildlife in consideration. The construction the wetlands, with associated mounds and shrub revegetation, is expected to have a positive effect on wildlife habitat relative to current conditions. The area, pre-construction, is a seasonally moist/wet field-type habitat dominated by invasive reed canarygrass. Establishing baseline data for this habitat before construction begins will allow us to assess how effective this technique will be at enhancing wildlife habitat.

Challenges associated with assessing the effectiveness of previous revegetation treatments and varied success in detecting any positive results from revegetation polygons may limit our ability to compare between the effectiveness of revegetation and wildlife physical works.

6.4 Management Questions - Summary

Management questions fall into two main components: 1) those of revegetation effectiveness monitoring, and 2) those of wildlife physical works. The original application and subsequent varied success of revegetation treatments (and other confounding factors such as inter- and intra-site specific differences) severely limits our ability to make quantitative inferences about treatment effects. Some useful information may be obtained by continued arthropod sampling, but continued bird sampling in most of the study sites is unlikely to yield additional data that would allow for a greater quantitative approach. However, we have gathered much baseline information on the Burton Creek Wildlife Physical Works location, which will allow us to make informed before-and-after wetland construction assessments. We recommend continued pre-treatment sampling at proposed physical works areas (until implementation) to further develop a baseline for assessing differences in future years. Until the physical works are implemented in Arrow Lakes Reservoir, we will not be able to answer questions regarding their effectiveness.

7.0 RECOMMENDATIONS

In 2017, the Terms of Reference for CLBMON-11B1 were revised (Revision 1, June 29, 2017, BC Hydro 2017). The work completed in 2018 thus represents the first year of implementation under these revised Terms of Reference. The recommendations provided below are intended to focus the assessment of specific revegetation prescriptions applied in the drawdown zone of Arrow Lakes Reservoir relative to their use by wildlife and allow for a greater assessment of Wildlife Physical Works conditions to enhance the suitability of the drawdown zone for wildlife.

1. **Discontinue bird point count sampling and nest searching at Revelstoke Reach sites (McKay Creek, 8 Mile, 9 Mile and 12 Mile) as well as at East Arrow, Edgewood North and Edgewood South**. The spatial pattern of revegetation treatment application within the drawdown zone is incongruent with bird territory sizes. Regarding point count design, it further limits our analysis to

those detections within 30 m as at distances beyond that most birds are no longer within the treatment area of interest. The resulting dataset is zero-inflated, with many single species or single observation detections, which significantly constrains analytical options. There are also few revegetation polygons at most sites which limits sample size. Surveying to date has shown no detectable difference in bird richness, diversity, or nesting preferences between treatment and control areas at most sites. However, Burton Creek remains an important site due to the Wildlife Physical Works location, and Lower Inonoaklin has seen success in both revegetation of Black Cottonwood, and bird usage of that habitat. We recommend reallocating effort to focus songbird surveys on these two areas.

2. **Continue to monitor spring and fall migrant waterfowl and shorebirds** in proposed physical works areas to obtain a baseline dataset associated with these bird groups. This is necessary to assess if constructed wetlands or other physical works will provide suitable habitat for birds. If the recommendation to discontinue songbird surveys at most sites is implemented, we recommend increasing the number of waterfowl surveys from the spring (April) through the fall (October) to obtain a more accurate understanding of temporal and spatial trends for birds in this area. If possible, surveys during the spring through fall should also include Lower Inonoaklin.
3. **Expand arthropod sampling within study sites to increase replication of revegetation treatments.** While overall arthropod biomass and CPUE was unchanged between control and revegetated polygons, more sampling points may rule out the possibility that our failure to detect an effect is due to sample sizes. One limiting factor this sampling period was the lack of replication of treatment type within and between some sites due to high reservoir levels. In 2019, as reservoir elevations permit, arthropod sampling should include additional polygons.
4. **Collect associated microsite data.** Although we have some measure of plant density in treatment polygons (Miller et al. 2018; Hawkes et al. 2018a), this does not account for yearly changes to vegetation and the vegetation structure of control polygons. Several of our measures of arthropod abundance and species richness (including arthropod biomass and Araneae species richness and diversity) positively responded to our measure of per cent live organic matter in polygons. This suggests that habitat features such as vegetation density can be a relevant consideration in determining arthropod presence and diversity. However, taxon responses also suggested that microsite conditions may differ between treatment and control areas within sites. Continuing to classify substrate and per cent live organic matter in each polygon would allow us to better understand arthropod use of revegetated and non-revegetated polygons. We also aim to classify the vertical structural heterogeneity within each polygon and deploy data loggers to record substrate temperature and relative humidity. This may allow us to better understand the variability in arthropod species responses.
5. **Increase the number of Malaise tents in the Burton Creek pre-treatment wildlife physical works area and discontinue the use of Malaise tents in revegetated polygons.** Malaise tents are a useful tool in monitoring flying arthropods, but their current number in revegetated polygons (n≤2) precludes any strong inference being made from the collected insects. We propose to discontinue their use in measuring biomass or diversity in revegetated polygons. However, they would be useful in providing information on the pre-treatment

baselines of flying insects in the wildlife physical works area. We propose increasing the number of Malaise tents to three per collection round in the wildlife physical works area. A greater number of Malaise tents would also allow us to measure insect diversity as well as insect biomass, with three collection days per collection period dedicated to measuring biomass and the final day dedicated to measuring diversity.

6. **Targeted sampling of Dragonflies and Damselflies (Order: Odonata) in the Burton Creek Wildlife Physical Works site.** As a compliment to Malaise tent diversity measures, hand-sampling odonates should be added to the monitoring at the Burton Creek WPW site in order to provide appropriate baseline of macroinvertebrates in the area. CLBWORKS-29B specifically mentions Odonates as taxa predicted to benefit from the creation of the wetland habitat at this site (Hawkes and Tuttle 2016). Thus, pre-treatment data on the abundance and diversity of Odonata using the current site is needed. Identification to species will be done in the field or confirmed later by photographs. Voucher specimens may be hand-collected as necessary. Start and end time of searches, UTM location, and weather would be recorded for each survey.
7. **Conduct targeted surveys for amphibians and reptiles in the Burton Creek Wildlife Physical Works site.** These data would compliment those collected under LBMON-37 and would ensure the development of a baseline data set for the physical works location.
8. **Document pre-treatment wildlife use of Burton Creek Wildlife Physical Works site with remote cameras.** While incidental observations of wildlife have proven useful to document species presence across various sites in Arrow Lakes Reservoir, incidental data cannot be used to assess changes in habitat use. We propose pairing remote cameras with the bat detector set-up at the WPW site to collect baseline, pre-treatment data on wildlife activity at this site throughout the summer of 2019. Remote cameras have the potential to provide more complete information about the range of species using the existing habitat. It is expected that the proposed wetland project will increase habitat suitability for a variety of wildlife, thus, we expect an increase in species richness using this site.

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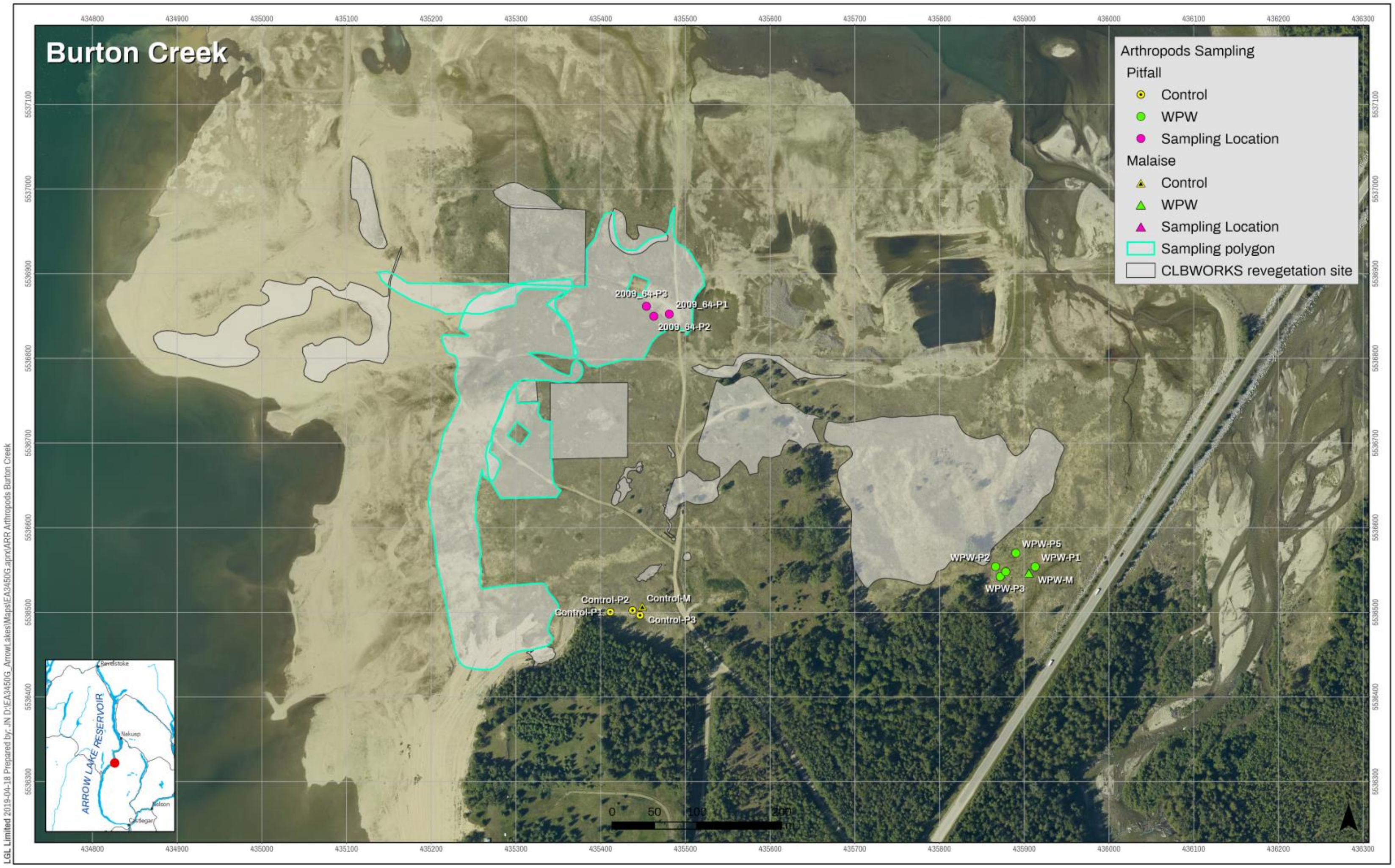
9.0 APPENDICES

Appendix A: Maps of Malaise and pitfall trap locations for 2018

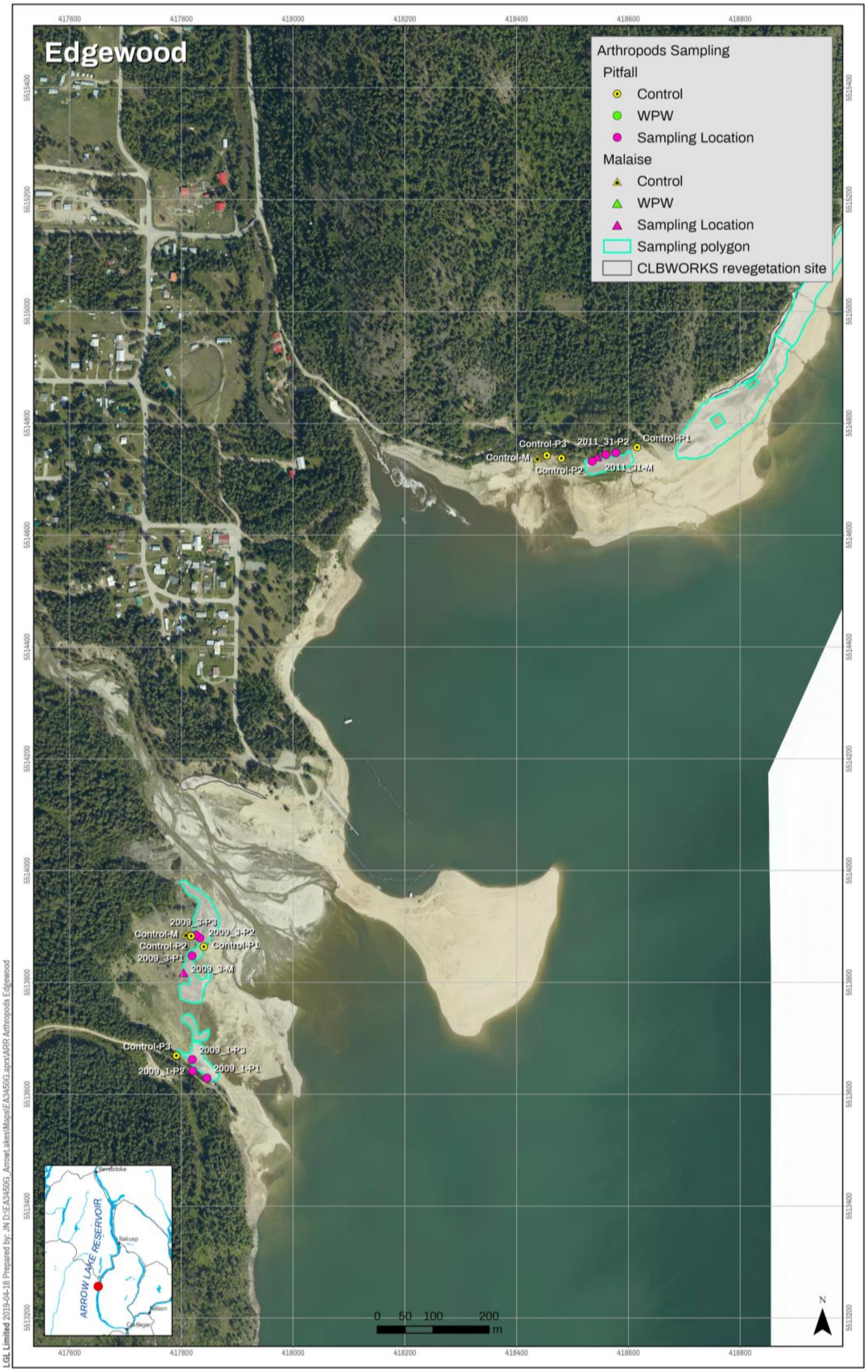
Map 1: **Distribution of Malaise and pitfall traps at 9 Mile (Revelstoke Reach)**

Map 2: **Distribution of Malaise and pitfall traps at 12 Mile (Revelstoke Reach)**



Map 3: **Distribution of Malaise and pitfall traps at Burton Creek**

Map 4: **Distribution of Malaise and pitfall traps at Lower Inonoaklin**



Map 5: **Distribution of Malaise and pitfall traps at Edgewood North and Edgewood South**

Appendix B: Sampling locations for arthropods and songbirds in 2018. Treatment information were derived from CLBMON-35 (Hawkes et al. 2018a, draft) and CLBMON-12 (Miller et al. 2018). PCS= point count station, NS= nest search, PF= pitfall trap array, M= Malaise trap.

Study Site	Polygon ID	Revegetation Treatment*	Transplant Species	Songbird sampling	Arthropod sampling
Burton	2009_25	Stake	Black cottonwood, Willow sp., Red-osier dogwood	3 PCS	
	2009_64	graminoid	Columbia sedge, Water sedge, Kellogg's sedge, Wool-grass	1 PCS	3 PF
	Control	Control		1 PCS	3 PF, 1 M
	WPW	Pre-treatment		5 PCS	5 PF, 1 M
Lower Inonoaklin	2009_13	Stake	Black cottonwood, Willow sp., Columbia sedge	2 PCS	
	2009_16	Stake	Black cottonwood, Willow sp.	1 PCS	
	2009_18	Stake	Black cottonwood, Willow sp.	2 PCS	3 PF, 1 M
	2009_19	graminoid	Columbia sedge, Bluejoint reedgrass	1 PCS	
	2011_23	graminoid	Kellogg's sedge	3 PCS	3 PF
	Control	Control		1 PCS	3 PF, 1 M
Edgewood South	2009_1	Stake	black cottonwood, willow sp.	1 PCS	3 PF
	2009_3	Stake	black cottonwood, willow sp.	3 PCS	3 PF, 1 M
	Control	Control		2 PCS	3 PF, 1 M
Edgewood North	2009_7	graminoid	Columbia sedge, Water sedge, Kellogg's sedge, Wool-grass	1 PCS	
	2009_9	graminoid	Columbia sedge, Water sedge, Kellogg's sedge, Small-flowered bulrush	3 PCS	
	2011_31	graminoid	Water sedge, Kellogg's sedge, Red-osier dogwood Wool-grass	2 PCS	3 PF, 1 M
	Control	Control		2 PCS	3 PF, 1 M
East Arrow Park	2010_11	graminoid	Kellogg's sedge, Columbia sedge	1 PCS	
	2009_41	graminoid	Columbia sedge	3 PCS	
	2009_49	graminoid	Kellogg's sedge, Columbia sedge	3 PCS	
	Control	Control		1 PCS	
12 Mile	2010_RR11_A	Stake	Black cottonwood	1 PCS	3 PF, 1 M
	2010_RR11_B	Stake	Black cottonwood	1 PCS	
	2010_RR12	Stake	Black cottonwood	1 PCS	
	2010_RR9	Stake	Black cottonwood	3 PCS	
	2009_87	graminoid	Kellogg's sedge, Columbia sedge	1 PCS	
	Control	Control		2 PCS	3 PF, 1 M
McKay Creek	2010_RR4_A	Stake	Black cottonwood	1 PCS	
	2010_RR4_B	Stake	Black cottonwood	1 PCS	
	2010_RR4_C	Stake	Black cottonwood	1 PCS	
	2010_RR2_A	Stake	Black cottonwood	1 PCS	
	2010_RR2_C	Stake	Black cottonwood	1 PCS	
	2010_RR2_E	Stake	Black cottonwood	1 PCS	
	Control	Control		3 PCS	
8 Mile	2010_RR5_A	Stake	Black cottonwood,	3 PCS	

Study Site	Polygon ID	Revegetation Treatment*	Transplant Species	Songbird sampling	Arthropod sampling
			Red-osier dogwood		
	2010_RR5_C	Stake	Black cottonwood	3 PCS	
	Control	Control		4 PCS	
9 Mile	2010_RR8	Stake	Black cottonwood, Red-osier dogwood	3 PCS	3 PF, 1 M
	Control	Control		3 PCS	3 PF, 1 M

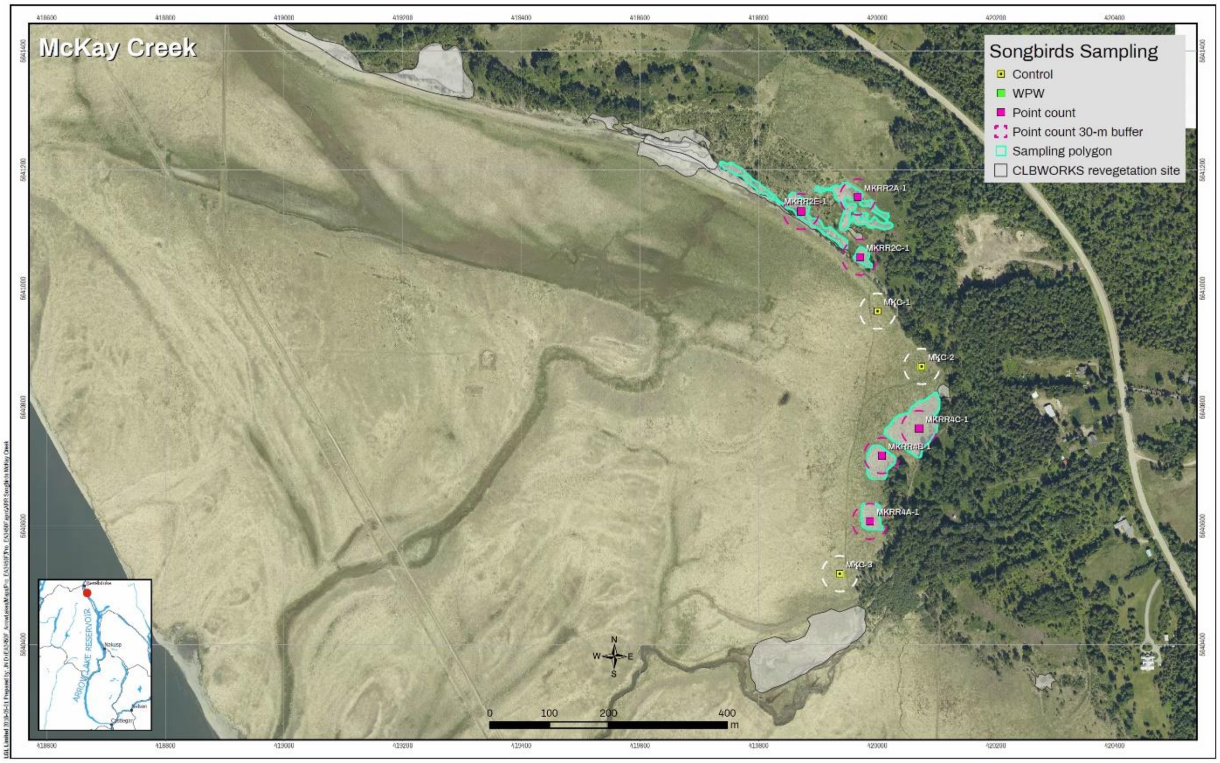
Appendix C: **Dates of trap setup and collection for arthropod sampling in 2018.** M = Malaise trap, P= pitfall trap array. Empty cells indicate that no collection was made.

Study Site	Polygon	Trap	Collection 1	Collection 2
12 Mile	**2010_RR11_A**	M, P1, 2, 3	3 to 6 Jun 2018	21 to 24 Jun 2018
	Control	M, P1, 2, 3	3 to 6 Jun 2018	21 to 24 Jun 2018
9 Mile	**2010_RR8**	M, P1, 2, 3	3 to 6 Jun 2018	21 to 23 Jun 2018
	Control	M, P1, 2, 3	3 to 6 Jun 2018	21 to 24 Jun 2018
Burton	**2009_64**	P1	8 to 11 Jun 2018	
		P2	8 to 10 Jun 2018	
		P3	8 to 9 Jun 2018	
	Control	M	8 to 11 Jun 2018	23 to 26 Jun 2018
		P1	8 to 11 Jun 2018	
		P2, 3	8 to 11 Jun 2018	23 to 26 Jun 2018
	WPW	M, P1, 2, 3, 4, 5	8 to 11 Jun 2018	23 to 26 Jun 2018
Edgewood North	**2011_31**	M, P1, 2, 3	7 to 10 Jun 2018	
	Control	M, P1, 2, 3	7 to 10 Jun 2018	
Edgewood South	**2009_1**	P1, 2, 3	7 to 10 Jun 2018	
	2009_3	M, P1, 2, 3	7 to 10 Jun 2018	
	Control	M, P1, 2, 3	7 to 10 Jun 2018	
Lower Inonoaklin	**2009_18**	M	7 to 10 Jun 2018	
		P1, 2, 3	7 to 10 Jun 2018	25 to 27 Jun 2018
	2011_23	P1, 2	7 to 10 Jun 2018	
	Control	M	7 to 10 Jun 2018	
		P1, 2, 3	7 to 10 Jun 2018	25 to 27 Jun 2018

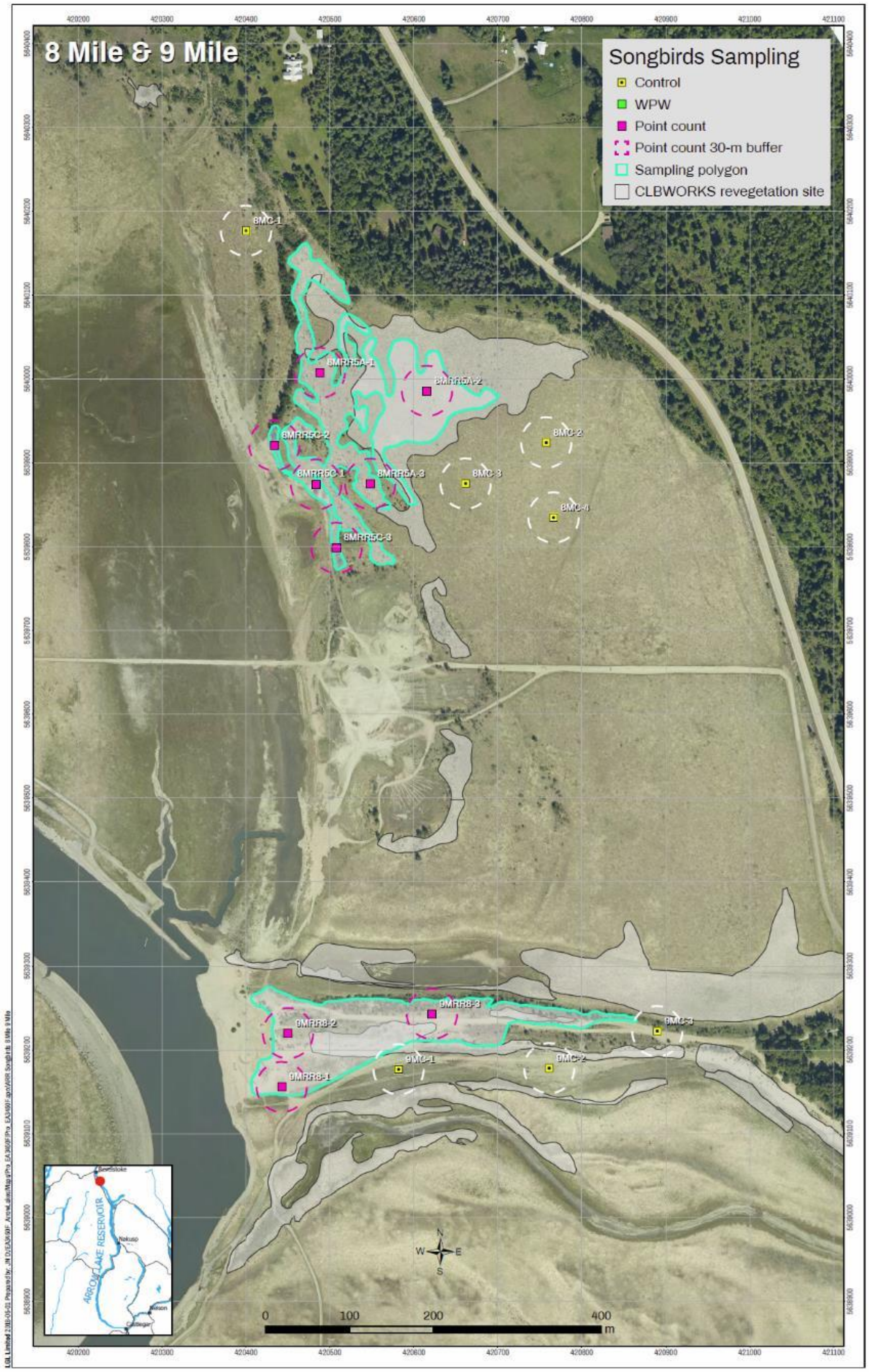
Appendix D: Number of point count stations by year, site, and habitat type. WPW = Wildlife Physical Works

Site	Treatment Type				Total
	Control	Graminoid	Stake	WPW	
8 Mile	4	0	6		10
9 Mile	3	0	3		6
12 Mile	2	1	6		9
McKay Creek	3	0	6		9
Burton Creek	1	1	3	5	10
East Arrow Park	1	7	0		8
Edgewood North	2	6	0		8
Edgewood South	2	0	4		6
Lower Inonoaklin	1	4	5		10
Total	*19*	*19*	*33*	*5*	*76*

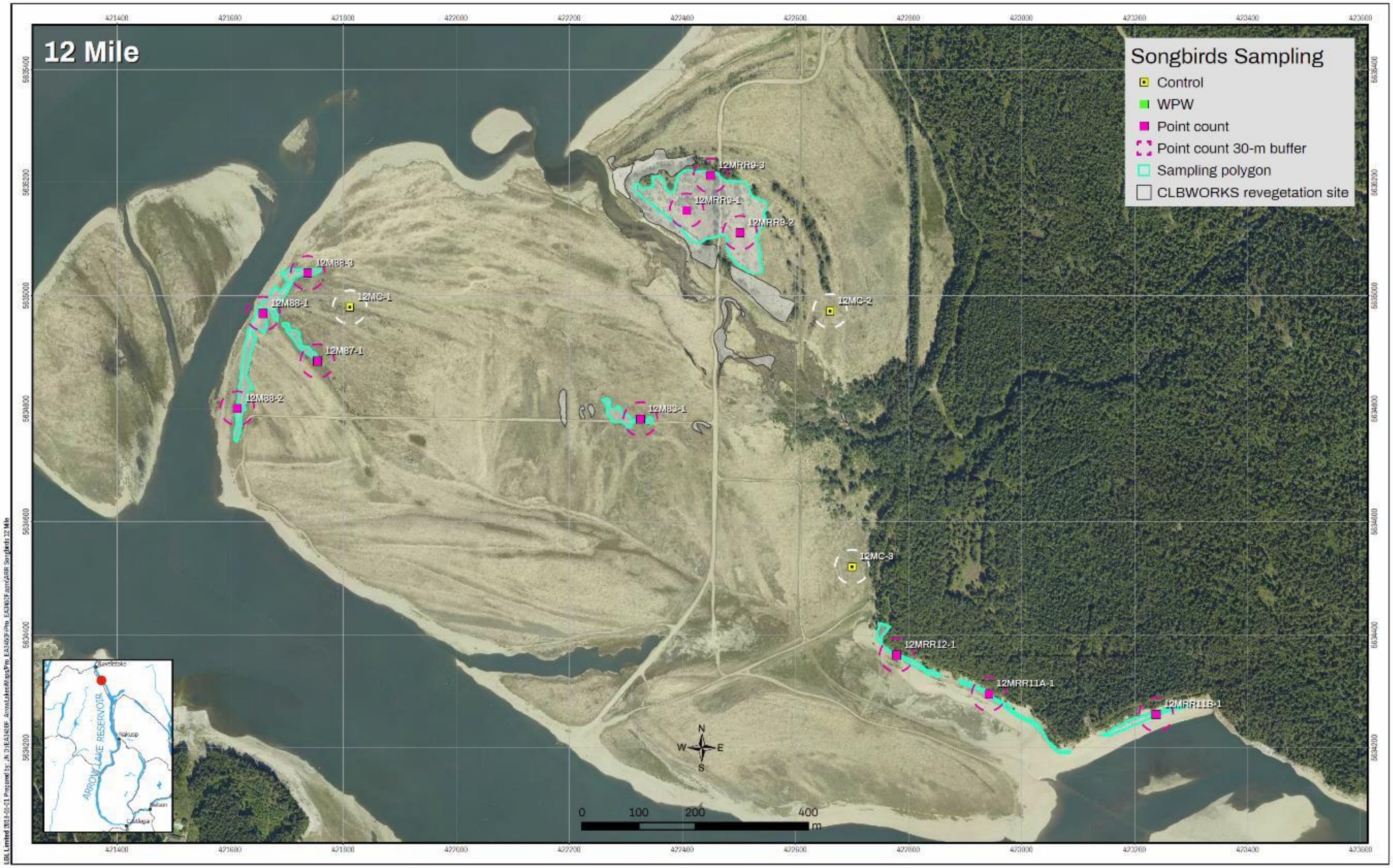
Appendix E: Maps of songbird point count and bat autonomous recording unit stations for 2018.



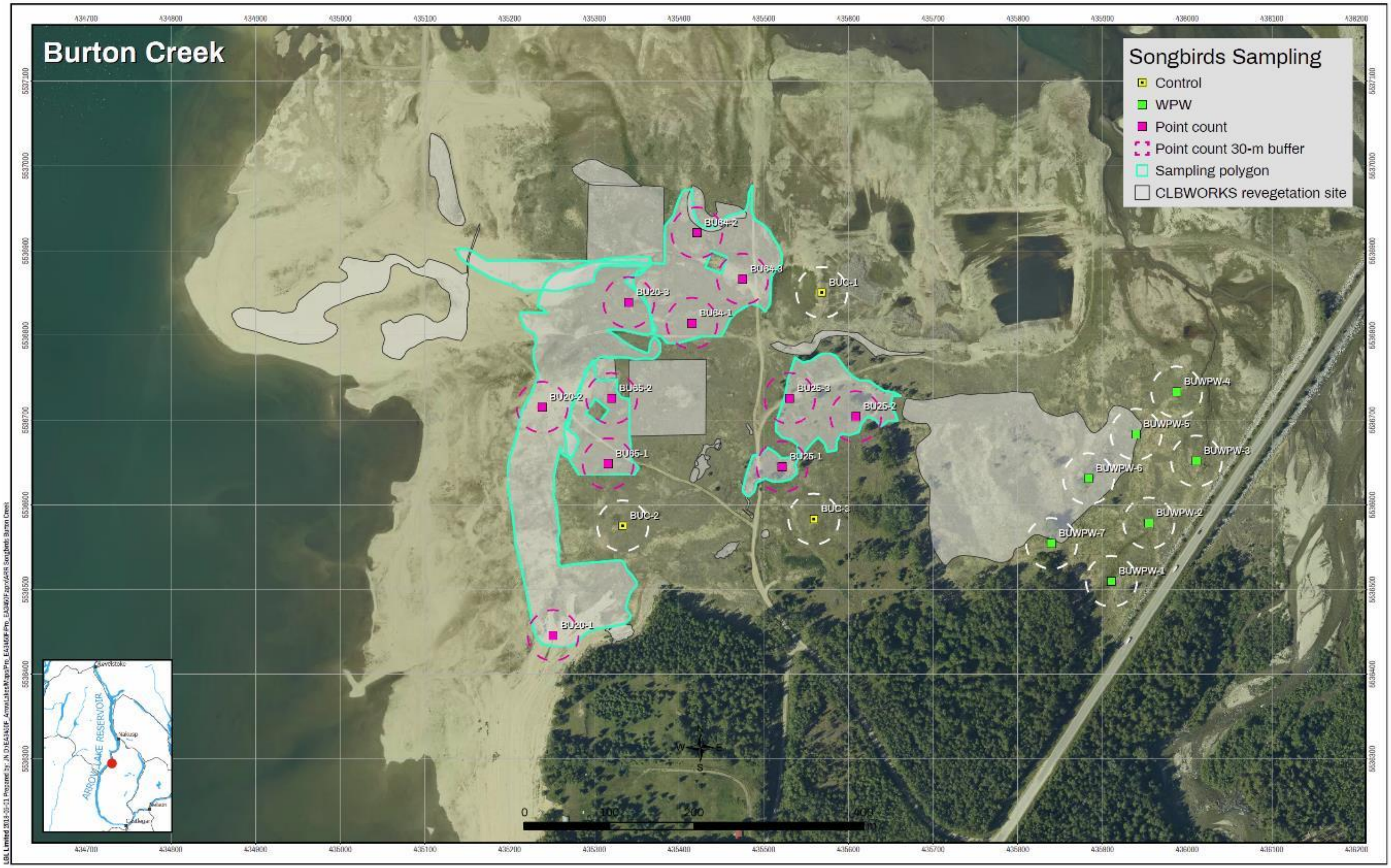
Map 6: Distribution of songbird point count stations at McKay Creek (Revelstoke Reach)



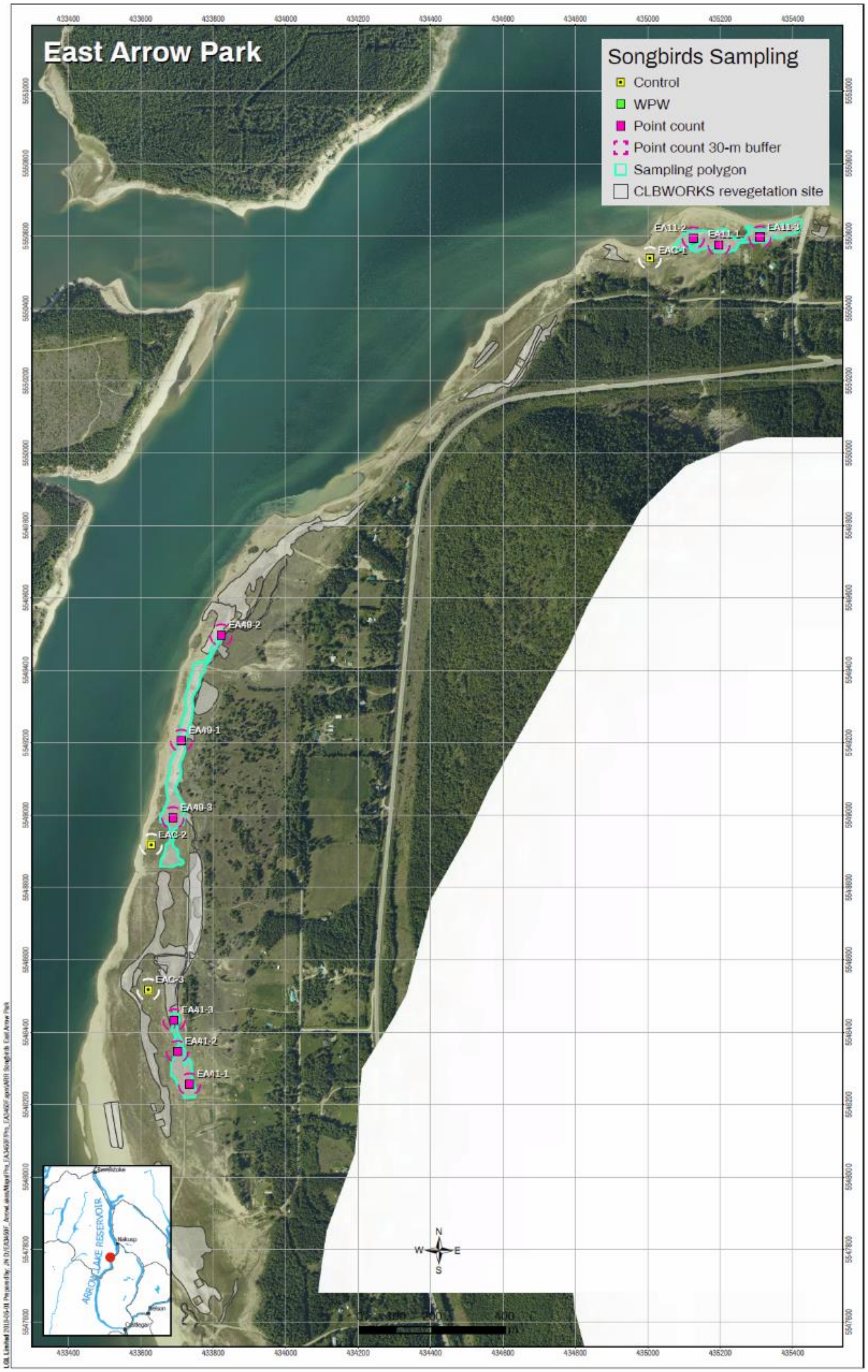
Map 7: **Distribution of songbird point count stations at 8 Mile and 9 Mile (Revelstoke Reach)**



Map 8: **Distribution of songbird point count stations at 12 Mile (Revelstoke Reach)**

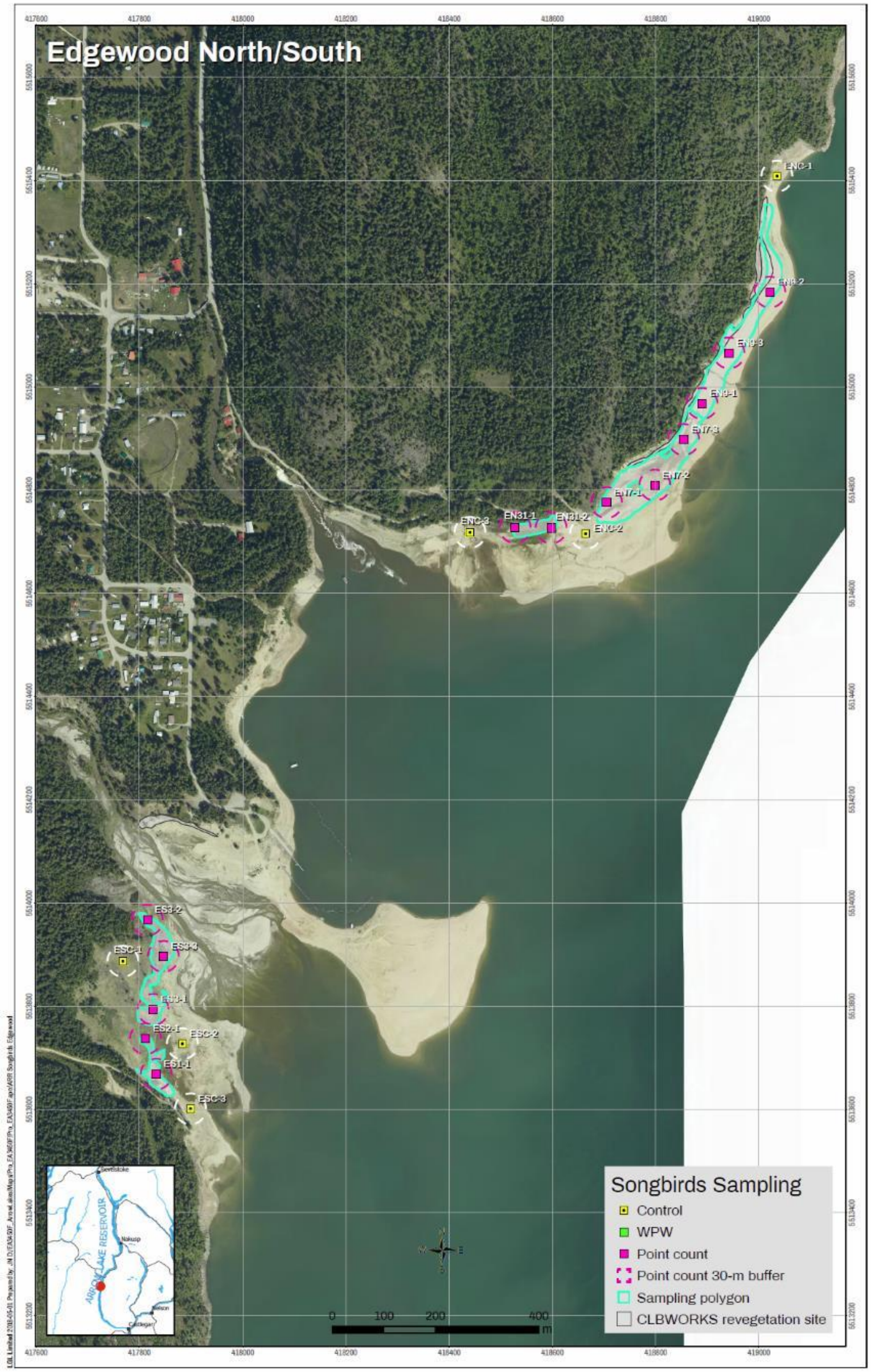


Map 9: **Distribution of songbird point count stations and bat autonomous recording units at Burton Creek**



Map 10: Distribution of songbird point count stations at East Arrow Park

Map 11: **Distribution of songbird point count stations and bat autonomous recording units at Lower Inonoaklin**



Map 12: **Distribution of songbird point count stations and bat autonomous recording units at Edgewood North and Edgewood South**

Map 13: **Distribution of bat autonomous recording unit at Armstrong Lake**

Appendix F: General monitoring of bat species and activity across Arrow Lakes Reservoir in 2018.

Background

In British Columbia there are 16 known bat species[4], with an additional three species reported as accidental occurrences (e.g., outside of the normal range). Twelve of these species are thought to potentially occur in the West Kootenays (Table 9-1). Live-capture studies have confirmed the presence of all those species except Western Small-footed Myotis (*Myotis ciliolabrum*). Five of these twelve species are of conservation concern at the provincial and/or national level. While bats are not able to be used for detecting differences on the spatial scale of the CLBWORKS-2 revegetation polygons, we select bats for monitoring across the reservoir drawdown zone and non-drawdown zone habitats as these data are important documentation of species at risk utilizing Arrow Lakes Reservoir. In addition, these bat data may be useful for comparisons to the bat activity recorded in future years of monitoring at the Burton wildlife physical works site.

Townsend's Big-eared Bat (*Corynorhinus townsendii*), Western Small-footed Myotis, Northern Myotis (*M. septentrionalis*), and Fringed Myotis (*M. thysanodes*) are blue-listed by the Conservation Data Centre (CDC), which is a status assigned to species that are particularly sensitive to impacts from human activities or natural events (BC CDC 2019). Federally, Northern Myotis and Little Brown Myotis (*M. lucifugus*) were emergency listed under the Species at Risk Act as Endangered (Dec. 17, 2014) due to the potential threat of White Nose Syndrome, a fungus caused by *Pseudogymnoascus destructans* that has been spreading westward since it was first documented in North America (COSEWIC 2013). Fringed Myotis is considered Data Deficient by COSEWIC, meaning there is not enough scientific information available to support status designation.

Table 9-1: Provincial and national status of bat species potentially occurring in the Lower and Mid-Arrow Lakes area

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

Methods

To study bat presence and distribution over and adjacent to the drawdown zone, Wildlife Acoustics Song Meter autonomous recording units (SM2BAT, SM2BAT+,

[4] Note: *Myotis keenii* has been suggested to be equivalent to *M. evotis* in B.C. (Lausen et al. 2018), but until a formal synonymy is published, it is retained here.

and SM3BAT) were deployed from June 4th to September 18th in 2018. Each unit was programmed with a schedule to document bats during two periods: i) half an hour before sunset for 5.5 hours, and ii) an hour before sunrise for 1.5 hours, for a total of 7 hours per 24-hour period.

A total of 11 bat detectors were deployed in the Lower and Mid-Arrow Lakes region from four sites: Burton Creek (n=4), Lower Inonoaklin (n=3), Edgewood South (n=3), and Armstrong Lake (n=1) (Appendix E). The detector at Armstrong Lake served as a non-reservoir reference. Based on the mobility of foraging bats, and the limited extent of revegetation treatments, we are unable to deploy bat detectors in a way that explicitly tests Treatment vs. Control areas.

Under ideal conditions, Wildlife Acoustics Song Meter detectors will sample bats in an airspace of 30 to 100 m from the microphone, with bats emitting higher frequencies (e.g., *Myotis septentrionalis*) detected more often in the 30 m zone and bats emitting lower frequencies (e.g., *Lasionycteris noctivagans* and *Lasiurus cinereus*) detected up to ~100 m from the microphone. The microphone paired with a Song Meter unit is omnidirectional, meaning that it will sample from almost all directions projecting out from the microphone. The microphones were set approximately 2 m above ground or higher, attached to either extendable aluminum poles or tree branches, and the pitch of the microphone was set at approximately 90° (horizontal).

Analysis

The same analysis methods as outlined in Section 4.6.4, were employed for bat recordings from drawdown zone sites and one non-reservoir location (Armstrong Lake). The only difference was the inclusion of an additional bat species classifier at one study site. Western Small-footed Myotis, which appears to be limited to dry, low elevation valleys in the interior of British Columbia (Garcia *et al.* 1995), was recommended for inclusion solely at Edgewood South (C. Lausen, PhD, Birchdale Ecological, pers. comm.). Bat frequencies are provided in Table 9-2. We present our bat detections as “indicative” rather than definitive.

Table 9-2: Typical frequencies (kHz) of calls from bat species expected to occur in habitats associated with the drawdown zone of the Lower and Mid-Arrow Lakes Reservoir

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

Bat species richness was summarized for each site. Similarly, the relative proportions of detections for each species were calculated and compared across sites. Data collected by autonomous recording devices do not provide an indication of the number of individual bats present in a given area and the assignment of species is based on a probability that the species is present.

Results

The eleven bat detectors deployed in Lower and Mid-Arrow Lakes were operational for a combined total of 4,728 hours. A total of 189,830 bat calls were recorded, and 105,920 (55.8%) files were assigned to a species using the Kaleidoscope Pro software. All 12 bat species that are expected to occur in the study area were documented. The distribution of species detections is given in Table 9-3.

Little Brown Myotis (MYOLUC) was detected 46,663 times, making it the most frequently recorded species overall. Yuma Myotis (MYOYUM) was the next most commonly recorded species with 17,800 assigned detections. It was also the only species to have more associated recordings than MYOLUC at detector LI02. Of the larger bat species, Silver-haired Bat (LASNOC) had the highest number of detections (13,902), followed by Hoary Bat (LASCIN, 12,596). Townsend's Big-eared Bat (CORTOW) and Fringed Myotis (MYOTHY) were the most infrequently detected species with only 12 and 25 total detections, respectively.

Table 9-3: Total number of recordings for each bat species documented from Arrow Lakes Reservoir in 2018. Numbers of recordings are not standardized for sampling effort. "N/A" indicates a species was omitted from analysis for the site based on low probability of occurrence. *n* = number of detectors deployed at each site. Species codes are provided in Table 9-1.

Species	Armstrong Lake (n=1)	Burton Creek (n=4)	Edgewood South (n=3)	Lower Inonoaklin (n=3)
CORTOW	2	2	2	6
EPTFUS	40	99	162	372
LASCIN	582	1136	3320	7558
LASNOC	1779	1484	2642	7997
MYOCAL	1270	872	2937	3695
MYOCIL	N/A	N/A	2368	N/A
MYOEVO	37	114	264	414
MYOLUC	9256	8275	11158	17974
MYOSEP	2	8	6	12
MYOTHY	0	8	11	6
MYOVOL	117	882	429	822
MYOYUM	692	2179	1440	13489
Richness	**10**	**11**	**12**	**11**

The number of bat recordings per detector-hour (measure of relative abundance) was highest at Lower Inonoaklin (LI01 and LI02), followed by detector ES03 at Edgewood South (Figure 9-1).

Relative abundance of species calls varied both within and across sites. All sites shared a greater prevalence of *Myotis* species compared to larger bat species (i.e., CORTOW, EPTFUS, LASCIN and LASNOC; Figure 9-1). Larger bat species combined represented on average ~25.7% of the total number of detections, ranging from 13.4 (at BU WPW) to 34.1% (at BU C).For example, large bat species (i.e., CORTOW, EPTFUS, LASCIN and LASNOC) accounted for 47.9% of all classified bats by detector LI01, while these represented only 8.2% of recordings at neighboring detector LI02 (Figure 9-1). Species composition also varied within and across sites. For example, Western Small-footed Myotis (MYOCIL) was detected solely at locations within Edgewood South, with one particular detector (ES03) recording 5 times more MYOCIL calls than the two nearby units (Figure 9-1).

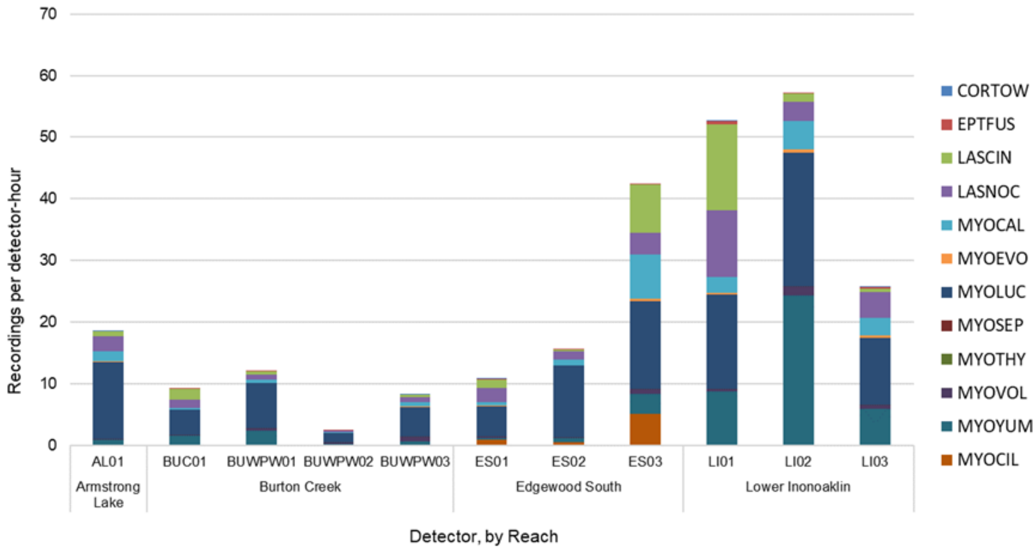


Figure 9-1: Relative abundance (recordings per detector-hour) of bat species by detector and site within Arrow Lake Reservoir, summer 2018. Burton Creek had two different habitat types sampled: BUC = Control, and BUWPW = Wildlife Physical Works.

Discussion

The results indicate a diverse assemblage of twelve bat species utilizing drawdown zone habitats within mid- and lower- Arrow Lakes Reservoir. The presence of species of conservation concern in this area is important to document. The federally endangered Little Brown Myotis (*M. lucifugus*) was the most commonly detected species across all study sites. In British Columbia, this species is designated as secure (yellow), but in other areas of its range, this species has exhibited severe declines attributed in part to the spread of White-nose Syndrome (COSEWIC 2013). The federally endangered and provincially blue-listed Northern Myotis (*M. septentrionalis*) was found in low occurrence, across all index sites (drawdown zone: Edgewood South, Lower Inonoaklin, and Burton; non-reservoir: Armstrong Lake). Likewise, the blue-listed Townsend's Big-eared Bat (*Corynorhinus townsendii*) and Fringed Myotis (*M. thysanodes*) were detected in low numbers of calls across all drawdown zone sites.

In addition, we found evidence of Western Small-footed Myotis (*Myotis ciliolabrum*) at Edgewood South. This species is blue-listed in British Columbia, which is the northern extent of its North American distribution. While not conclusive, these recordngs suggest the potential that this site is being used by this bat species in 2018 and previous years (e.g., Hawkes et al. 2018b; Sharkey et al. 2018; Wood et al. 2018).

These species classifications were determined using machine learning algorithms, and have the potential to make classification errors, thus we used conservative settings when determining species identifications. Nevertheless, Due to the aerial foraging and strong flight ability of bats, it is not possible to discern treatment level effects.

Appendix G: Spider and ground beetle species identified in 2018 diversity pitfall trap samples. Spider species identified in 2018 diversity pitfall trap samples with corresponding species codes. Presence (P) of each species is given for revegetation treatment (graminoid and stake), control, and Wildlife Physical Works (WPW pre-treatment) polygons.

Family	Species	Code	Control	Treatment	WPW
Order: Araneae (Spiders)					
Clubionidae	*Clubiona riparia*	*Club.ripa*			P
Gnaphosidae	*Callilepis pluto*	*Call.plut*	P	P	
	Gnaphosa muscorum	*Gnap.musc*		P	
	Gnaphosa parvula	*Gnap.parv*	P		P
	Micaria pulicaria	*Mica.puli*			P
	Micaria rossica	*Mica.ross*		P	
	Zelotes exiguoides	*Zelo.exig*		P	
	Zelotes puritanus	*Zelo.puri*			P
Hahniidae	*Neoantistea agilis*	*Neoa.agil*	P	P	P
	Neoantistea magna	*Neoa.magn*	P	P	P
Linyphiidae	*Collinsia ksenia*	*Coll.ksen*		P	
	Erigone aletris	*Erig.alet*	P		
	Erigone cristatopalpus	*Erig.cris*		P	
	Erigone dentosa	*Erig.dent*	P	P	
	Erigone paradisicola	*Erig.para*		P	
	Gnathonarium taczanowskii	*Gnat.tacz*	P		
	Grammonota gentilis	*Gram.gent*		P	
	Oedothorax alascensis	*Oedo.alas*			P
	Oreonetides filicatus	*Oreo.fili*	P		
Liocranidae	*Agroeca ornata*	*Agro.orna*	P		P
Lycosidae	*Pardosa altamontis*	*Pard.alta*	P	P	P
	Pardosa fuscula	*Pard.fusc*	P		P
	Pardosa groenlandica	*Pard.groe*	P	P	
	Pardosa mackenziana	*Pard.mack*			P
	Pardosa moesta	*Pard.moes*	P	P	P
	Pardosa wyuta	*Pard.wyut*	P		
	Pardosa xerampelina	*Pard.xera*	P	P	P
	Pirata piraticus	*Pira.pira*		P	P
	Trochosa ruricola	*Troc.ruri*			P
	Trochosa terricola	*Troc.terr*	P	P	P
Salticidae	*Habronattus hirsutus*	*Habr.hirs*	P		
Thomisidae	*Xysticus elegans*	*Xyst.eleg*	P		P
	Xysticus ellipticus	*Xyst.elli*		P	
	Xysticus ferox	*Xyst.fero*	P	P	P
Order: Coleoptera (Beetles)					
Carabidae	*Agonum corvus*	*Agon.corv*	P	P	P
	Agonum cupripenne	*Agon.cupr*	P	P	
	Agonum decorum	*Agon.deco*		P	
	Agonum harrisii	*Agon.harr*	P	P	
	Agonum metallescens	*Agon.meta*	P	P	
	Agonum muelleri	*Agon.muel*		P	
	Agonum piceolum	*Agon.pice*	P	P	P
	Agonum propinquum	*Agon.prop*		P	
	Agonum sordens	*Agon.sord*	P		
	Agonum suturale	*Agon.sutu*	P	P	
	Agonum thoreyi	*Agon.thor*			P
	Amara aenea	*Amar.aene*		P	
	Anisodactylus binotatus	*Anis.bino*	P	P	
	Bembidion bimaculatum	*Bemb.bima*	P	P	P
	Bembidion incrematum	*Bemb.incr*		P	
	Bembidion nigripes	*Bemb.nigr*		P	
	Bembidion quadrulum	*Bemb.quad*		P	
	Bembidion transparens	*Bemb.tran*			P
	Bembidion zephyrum	*Bemb.zeph*		P	
	Bradycellus congener	*Brad.cong*		P	
	Bradycellus harpalinus	*Brad.harp*		P	
	Carabus granulatus	*Cara.gran*	P	P	P
	Chlaenius niger	*Chla.nige*			P

Family	Species	Code	Control	Treatment	WPW
	Chlaenius pensylvanicus	*Chla.pens*		P	
	Cicindela oregona	*Cici.oreg*	P	P	
	Cicindela terricola	*Cici.terr*	P		
	Cicindela tranquebarica	*Cici.tran*	P		
	Clivina fossor	*Cliv.foss*	P	P	P
	Elaphrus americanus	*Elap.amer*	P	P	
	Harpalus affinis	*Harp.affi*	P	P	
	Loricera pilicornis	*Lori.pili*	P	P	
	Nebria gyllenhali	*Nebr.gyll*	P	P	
	Nebria mannerheimii	*Nebr.mann*	P		
	Omophron ovale	*Omop.oval*		P	
	Oxypselaphus pusillus	*Oxyp.pusi*		P	
	Patrobus fossifrons	*Patr.foss*	P	P	
	Poecilus lucublandus	*Poec.lucu*	P	P	P
	Pterostichus herculaneus	*Pter.herc*	P		
	Pterostichus melanarius	*Pter.mela*	P	P	P
	Pterostichus strenuus	*Pter.stre*		P	
	Scaphinotus angusticollis	*Scap.angu*	P	P	
	Stenolophus incultus	*Sten.incu*		P	P
	Syntomus americanus	*Synt.amer*	P	P	
	Trechus chalybeus	*Trec.chal*			P

Appendix H: Additional substrate and canopy cover (CC) data fit to RDA analyses of spider and beetle assemblage response to site conditions and revegetation.

SITE	REVEGETATION	POLYGON	TRAP	CC	LOM	MOSS	CWD	FWD	ROCK	MINERAL	MIXED	PEAT	LITTER
12M	Control	Control	P1	0	5	5	0	0	5	45	0	0	45
12M	Control	Control	P2	0	55	50	0	0	1	33	0	0	15
12M	Control	Control	P3	0	5	0	0	0	0	95	0	0	5
12M	Stake	2010_RR11_A	P2	55	10	0	10	5	1	39	0	0	45
12M	Stake	2010_RR11_A	P3	0	5	0	1	0	0	89	0	0	10
9M	Control	Control	P1	5	30	20	0	0	0	0	0	40	40
9M	Control	Control	P2	0	5	0	0	0	0	99	0	0	1
9M	Control	Control	P3	0	95	93	0	0	0	0	7	0	0
9M	Stake	2010_RR8	P1	0	5	1	5	0	0	0	89	0	5
BU	Control	Control	P1	0	10	1	0	0	1	5	63	0	30
BU	Control	Control	P2	0	40	0	0	0	0	0	10	0	90
BU	Control	Control	P3	0	30	0	5	0	0	0	5	0	90
BU	Graminoid	2009_64	P1	0	5	0	0	0	0	99	0	0	1
BU	Graminoid	2009_64	P2	0	40	0	0	0	0	5	0	0	95
BU	Graminoid	2009_64	P3	0	20	0	0	0	0	0	30	0	70
EN	Control	Control	P1	0	1	0	0	0	20	1	0	0	79
EN	Control	Control	P2	40	20	0	5	1	1	93	0	0	0
EN	Control	Control	P3	0	20	1	0	1	1	97	0	0	0
EN	Graminoid	2011_31	P1	0	40	10	0	0	15	70	0	0	5
EN	Graminoid	2011_31	P2	0	85	70	0	0	5	25	0	0	0
EN	Graminoid	2011_31	P3	0	10	1	0	0	10	89	0	0	0
ES	Control	Control	P1	0	5	0	0	0	0	99	0	0	1
ES	Control	Control	P2	0	10	0	0	0	0	0	0	0	100
ES	Control	Control	P3	75	10	10	0	10	10	30	5	0	35
ES	Stake	2009_1	P1	80	5	0	5	0	5	85	0	0	5
ES	Stake	2009_1	P2	80	30	25	0	5	1	64	0	0	5
ES	Stake	2009_1	P3	0	25	20	0	0	1	74	0	0	5
ES	Stake	2009_3	P1	0	10	1	0	0	10	0	5	0	84
ES	Stake	2009_3	P2	0	5	0	0	0	0	1	95	0	4
ES	Stake	2009_3	P3	75	15	5	0	0	0	1	84	0	10
LI	Control	Control	P1	0	5	0	0	0	10	85	0	0	5
LI	Control	Control	P2	0	15	0	0	0	5	0	1	0	94
LI	Control	Control	P3	0	5	0	0	1	0	90	0	0	9
LI	Stake	2009_18	P1	5	1	0	0	0	0	100	0	0	0
LI	Stake	2009_18	P2	40	1	0	0	0	70	29	0	0	1
LI	Stake	2009_18	P3	0	20	0	0	1	1	1	0	0	97
LI	Graminoid	2011_23	P1	0	30	0	0	0	0	0	50	0	50
LI	Graminoid	2011_23	P2	0	40	0	0	0	0	1	0	0	99
LI	Graminoid	2011_23	P3	0	5	0	0	0	80	10	0	0	10

Appendix I: Hymenopteran and Dipteran families with the greatest representation in Malaise trap samples, separated by site and polygon. Families were chosen based on the three highest proportions in each sample. Proportion is out of total number of individuals in sample. In cases where more than three families had similar proportions, all were included in the table.

Site	Polygon	Treatment	Family	Proportion of sample
Order: Hymenoptera				
12 Mile	2010_RR11_A	Stake	Andrenidae	0.20
12 Mile	2010_RR11_A	Stake	Ichneumonidae	0.20
12 Mile	2010_RR11_A	Stake	Diapriidae	0.20
12 Mile	Control	Control	Braconidae	0.42
12 Mile	Control	Control	Diapriidae	0.25
12 Mile	Control	Control	Ichneumonidae	0.17
9 Mile	2010_RR8	Stake	Vespidae	0.60
9 Mile	2010_RR8	Stake	Crabronidae	0.10
9 Mile	2010_RR8	Stake	Ichneumonidae	0.10
9 Mile	2010_RR8	Stake	Mymaridae	0.10
9 Mile	2010_RR8	Stake	Pteromalidae	0.10
9 Mile	Control	Control	Braconidae	0.27
9 Mile	Control	Control	Crabronidae	0.23
9 Mile	Control	Control	Vespidae	0.19
Burton	Control	Control	Diapriidae	0.17
Burton	Control	Control	Braconidae	0.12
Burton	Control	Control	Mymaridae	0.10
Edgewood North	2011_31	Graminoid	Ichneumonidae	0.36
Edgewood North	2011_31	Graminoid	Braconidae	0.19
Edgewood North	2011_31	Graminoid	Vespidae	0.07
Edgewood North	2011_31	Graminoid	Crabronidae	0.07
Edgewood North	Control	Control	Ichneumonidae	0.17
Edgewood North	Control	Control	Mymaridae	0.14
Edgewood North	Control	Control	Crabronidae	0.13
Edgewood South	2009_3	Stake	Ichneumonidae	0.34
Edgewood South	2009_3	Stake	Braconidae	0.09
Edgewood South	2009_3	Stake	Eulophidae	0.08
Edgewood South	Control	Control	Ichneumonidae	0.32
Edgewood South	Control	Control	Diapriidae	0.09
Edgewood South	Control	Control	Eulophidae	0.09
Lower Inonoaklin	2009_18	Stake	Mymaridae	0.13
Lower Inonoaklin	2009_18	Stake	Ichneumonidae	0.12
Lower Inonoaklin	2009_18	Stake	Encrytidae	0.10
Lower Inonoaklin	Control	Control	Ichneumonidae	0.23
Lower Inonoaklin	Control	Control	Diapriidae	0.14
Lower Inonoaklin	Control	Control	Pompilidae	0.09

Site	Polygon	Treatment	Family	Proportion of sample
Order: Diptera				
12 Mile	2010_RR11_A	Stake	Chironomidae	0.93
12 Mile	2010_RR11_A	Stake	Mycetophilidae	0.02
12 Mile	2010_RR11_A	Stake	Phoridae	0.01
12 Mile	Control	Control	Chironomidae	0.23
12 Mile	Control	Control	Ephydridae	0.22
12 Mile	Control	Control	Mycetophilidae	0.12
9 Mile	2010_RR8	Stake	Chironomidae	0.79
9 Mile	2010_RR8	Stake	Muscidae	0.09
9 Mile	2010_RR8	Stake	Anthomyiidae	0.03
9 Mile	Control	Control	Chironomidae	0.76
9 Mile	Control	Control	Muscidae	0.06
9 Mile	Control	Control	Sciaridae	0.04
Burton	Control	Control	Chironomidae	0.73
Burton	Control	Control	Ephydridae	0.05
Burton	Control	Control	Phoridae	0.05
Edgewood North	2011_31	Graminoid	Chironomidae	0.37
Edgewood North	2011_31	Graminoid	Phoridae	0.12
Edgewood North	2011_31	Graminoid	Ceratopogonidae	0.11
Edgewood North	Control	Control	Chironomidae	0.50
Edgewood North	Control	Control	Phoridae	0.09
Edgewood North	Control	Control	Anthomyiidae	0.08
Edgewood South	2009_3	Stake	Chironomidae	0.80
Edgewood South	2009_3	Stake	Phoridae	0.06
Edgewood South	2009_3	Stake	Ephydridae	0.04
Edgewood South	Control	Control	Chironomidae	0.49
Edgewood South	Control	Control	Phoridae	0.25
Edgewood South	Control	Control	Cecidomyiidae	0.06
Lower Inonoaklin	2009_18	Stake	Chironomidae	0.60
Lower Inonoaklin	2009_18	Stake	Phoridae	0.07
Lower Inonoaklin	2009_18	Stake	Dolichopodidae	0.05
Lower Inonoaklin	Control	Control	Chironomidae	0.34
Lower Inonoaklin	Control	Control	Phoridae	0.19
Lower Inonoaklin	Control	Control	Cecidomyiidae	0.11

Appendix J: Number of observations of all bird species detected from all distances during songbird point count surveys in 2018. Table sorted alphabetically by species code.

Bird Code	Common Name	Scientific Name	BC Status	COSEWIC	Study Site									
					MC	8M	9M	12M	EA	BU	LI	EN	ES	Total
ALFL	Alder Flycatcher	*Empidonax alnorum*	Yellow	.	2	6	2	2	1	1	1			15
AMCR	American Crow	*Corvus brachyrhynchos*	Yellow	.	1	1	1		4	4	6			17
AMGO	American Goldfinch	*Spinus tristis*	Yellow	.							1			1
AMPI	American Pipit	*Anthus rubescens*	Yellow	.			4							4
AMRE	American Redstart	*Setophaga ruticilla*	Yellow	.	19	8	3	7	4	3	12	7	8	71
AMRO	American Robin	*Turdus migratorius*	Yellow	.	4	6	2	1	7	4	16	4	9	53
AMWI	American Wigeon	*Mareca americana*	Yellow	.	9	6	2	3		1				21
BAEA	Bald Eagle	*Haliaeetus leucocephalus*	Yellow	Not at Risk		2		3		2	1		5	13
BCCH	Black-capped Chickadee	*Poecile atricapillus*	Yellow	.	1			1	2	2	1	1	1	9
BEKI	Belted Kingfisher	*Megaceryle alcyon*	Yellow	.		1		1				1	1	4
BHCO	Brown-headed Cowbird	*Molothrus ater*	Yellow	.	7	3	1	1	2	2	1		1	18
BHGR	Black-headed Grosbeak	*Pheucticus melanocephalus*	Yellow	.		1	1	3		2	1	2		10
BKSW	Bank Swallow	*Riparia riparia*	Yellow	Threatened					1	3	5	3	2	14
BOGU	Bonaparte's Gull	*Chroicocephalus philadelphia*	Yellow	.									1	1
BUOR	Bullock's Oriole	*Icterus bullockii*	Yellow	.	1	1								2
BWTE	Blue-winged Teal	*Spatula discors*	Yellow	.		1								1
CAGO	Canada Goose	*Branta canadensis*	Yellow	.	3	3	4	1	6	2	2			21
CAHU	Calliope Hummingbird	*Selasphorus calliope*	Yellow	.		1	1	1				1		4
CAVI	Cassin's Vireo	*Vireo cassinii*	Yellow	.							1	4		5
CBCH	Chestnut-backed Chickadee	*Poecile rufescens*	Yellow	.					1		1			2
CCSP	Clay-colored Sparrow	*Spizella pallida*	Yellow	.	1	12	3							16
CEWA	Cedar Waxwing	*Bombycilla cedrorum*	Yellow	.	7	4	1	3	1	7	6	1	2	32
CHSP	Chipping Sparrow	*Spizella passerina*	Yellow	.	1	9		3	4	14	11		5	47
COGR	Common Grackle	*Quiscalus quiscula*	Yellow	.							1			1
COHA	Cooper's Hawk	*Accipiter cooperii*	Yellow	Not at Risk									1	1

Bird Code	Common Name	Scientific Name	BC Status	COSEWIC	Study Site									
					MC	8M	9M	12M	EA	BU	LI	EN	ES	Total
COLO	Common Loon	*Gavia immer*	Yellow	Not at Risk	2		1		2	7	2	4		18
COME	Common Merganser	*Mergus merganser*	Yellow	.	1				1	1	1	2	2	8
CORA	Common Raven	*Corvus corax*	Yellow	.	1	6	2	1	1	3	5	2	1	22
COYE	Common Yellowthroat	*Geothlypis trichas*	Yellow	.	23	13	2	5	7	20	9	1	5	85
DEJU	Dark-eyed Junco	*Junco hyemalis*	Yellow	.				2					4	6
DOWO	Downy Woodpecker	*Dryobates pubescens*	Yellow	.	1									1
DUFL	Dusky Flycatcher	*Empidonax oberholseri*	Yellow	.					1	4		3		8
DUGR	Dusky Grouse	*Dendragapus obscurus*	Yellow	.		1								1
EAKI	Eastern Kingbird	*Tyrannus tyrannus*	Yellow	.		9	2			3	9		1	24
ECDO	Eurasian Collared-Dove	*Streptopelia decaocto*	Exotic	.		1								1
GADW	Gadwall	*Mareca strepera*	Yellow	.	1									1
GBHE	Great Blue Heron	*Ardea herodias*	Blue	.	4		1	1						6
GCKI	Golden-crowned Kinglet	*Regulus satrapa*	Yellow	.				2		1		2	1	6
GRCA	Gray Catbird	*Dumetella carolinensis*	Yellow	.	9	6		1	2	1	8	1	1	29
HAFL	Hammond's Flycatcher	*Empidonax hammondii*	Yellow	.		1		2				2		5
HAWO	Hairy Woodpecker	*Dryobates villosus*	Yellow	.						2	1		1	4
KILL	Killdeer	*Charadrius vociferus*	Yellow	.			4			1	3	1		9
LCSP	LeConte's Sparrow	*Ammospiza leconteii*	Yellow	.		2		1		1				4
LEFL	Least Flycatcher	*Empidonax minimus*	Yellow	.	17	7	1							25
LISP	Lincoln's Sparrow	*Melospiza lincolnii*	Yellow	.	3	6	1	1	1	1				13
LZBU	Lazuli Bunting	*Passerina amoena*	Yellow	.		3			5	18	4			30
MACW	MacGillivray's Warbler	*Geothlypis tolmiei*	Yellow	.	4	3		2		4	1	1		15
MALL	Mallard	*Anas platyrhynchos*	Yellow	.	2	7	2	4	1	12	2	2	4	36
MERL	Merlin	*Falco columbarius*	Yellow	Not at Risk					1					1
MGNW	Magnolia Warbler	*Setophaga magnolia*	Yellow	.				1						1
NAWA	Nashville Warbler	*Oreothlypis ruficapilla*	Yellow	.	1							7	5	13
NOFL	Northern Flicker	*Colaptes auratus*	Yellow	.		2	1	1	1		2			7
NOWA	Northern Waterthrush	*Parkesia noveboracensis*	Yellow	.		1								1

Bird Code	Common Name	Scientific Name	BC Status	COSEWIC	Study Site									
					MC	8M	9M	12M	EA	BU	LI	EN	ES	Total
NRWS	Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	Yellow	.		2		2			3	3		10
OCWA	Orange-crowned Warbler	*Oreothlypis celata*	Yellow	.	1									1
OSPR	Osprey	*Pandion haliaetus*	Yellow	.			1	1			5	3		10
PAWR	Pacific Wren	*Troglodytes pacificus*	Yellow	.				1						1
PISI	Pine Siskin	*Spinus pinus*	Yellow	.				1		1				2
PIWO	Pileated Woodpecker	*Dryocopus pileatus*	Yellow	.		3	2			1	1	1		8
PSFL	Pacific-slope Flycatcher	*Empidonax difficilis*	Yellow	.								2		2
RBNU	Red-breasted Nuthatch	*Sitta canadensis*	Yellow	.						1	1	2	1	5
REVI	Red-eyed Vireo	*Vireo olivaceus*	Yellow	.	17	9		3	2	14	5	10	6	66
RNSA	Red-naped Sapsucker	*Sphyrapicus nuchalis*	Yellow	.		1		2			2			5
RUGR	Ruffed Grouse	*Bonasa umbellus*	Yellow	.		2		1			1			4
RUHU	Rufous Hummingbird	*Selasphorus rufus*	Yellow	.	7	12	7	2		1	3	1	1	34
RWBL	Red-winged Blackbird	*Agelaius phoeniceus*	Yellow	.		3	1			3			2	9
SAVS	Savannah Sparrow	*Passerculus sandwichensis*	Yellow	.	1	8	2	3	1					15
SORA	Sora	*Porzana carolina*	Yellow	.	9	3	2	2		3			2	21
SOSA	Solitary Sandpiper	*Tringa solitaria*	Yellow	.	1					1	1			3
SOSP	Song Sparrow	*Melospiza melodia*	Yellow	.	5			1	1		7		2	16
SPSA	Spotted Sandpiper	*Actitis macularius*	Yellow	.	1	5	8	3	3	7	8	8	11	54
SPTO	Spotted Towhee	*Pipilo maculatus*	Yellow	.								1		1
SWSP	Swamp Sparrow	*Melospiza georgiana*	Yellow	.									1	1
SWTH	Swainson's Thrush	*Catharus ustulatus*	Yellow	.	1	2		5	5	2		9	3	27
TOWA	Townsend's Warbler	*Setophaga townsendi*	Yellow	.									4	4
TRSW	Tree Swallow	*Tachycineta bicolor*	Yellow	.	4	9	3	4	2		1			23
TUVU	Turkey Vulture	*Cathartes aura*	Yellow	.						1				1
UNLG	Unidentified Larus Gull	*Larus* (sp)	N/A	.				1		1			1	3
UNSW	Unidentified Swallow	*Hirundinidae* (gen, sp)	N/A	.				1						1
UNWO	Unidentified Woodpecker	*Picinae* (gen, sp)	N/A	.								1		1

Bird Code	Common Name	Scientific Name	BC Status	COSEWIC	Study Site									
					MC	8M	9M	12M	EA	BU	LI	EN	ES	Total
VASW	Vaux's Swift	*Chaetura vauxi*	Yellow	.			1	1						2
VATH	Varied Thrush	*Ixoreus naevius*	Yellow	.					1					1
VEER	Veery	*Catharus fuscescens*	Yellow	.	14	7	6	1			12			40
VGSW	Violet-green Swallow	*Tachycineta thalassina*	Yellow	.	1	1	1		2			2		7
VIRA	Virginia Rail	*Rallus limicola*	Yellow	.		1								1
WAVI	Warbling Vireo	*Vireo gilvus*	Yellow	.	7	1		2	3	7	2	3	6	31
WEME	Western Meadowlark	*Sturnella neglecta*	Yellow	.		4	2		4					10
WETA	Western Tanager	*Piranga ludoviciana*	Yellow	.	1	4	1	3	5			5	7	26
WIFL	Willow Flycatcher	*Empidonax traillii*	Yellow	.	8	3	8	8	6		25		14	72
WISN	Wilson's Snipe	*Gallinago delicata*	Yellow	.		2	3	8						13
WIWA	Wilson's Warbler	*Cardellina pusilla*	Yellow	.	2	1	1	2			1		1	8
WWPE	Western Wood-Pewee	*Contopus sordidulus*	Yellow	.	14	7	3	3		1	2	7	7	44
YEWA	Yellow Warbler	*Setophaga petechia*	Yellow	.	15	18	6	4	1	3	12	6	5	70
YHBL	Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	Yellow	.							2			2
YRWA	Yellow-rumped Warbler	*Setophaga coronata*	Yellow	.				3	2	9		9	7	30
		Totals			236	241	100	122	94	182	208	125	142	1450

Appendix K: Bird nests located during 2018 nest surveys, including nest location and fate.

Site: MC = McKay Creek (Revelstoke Reach); 8 M = 8 Mile (Revelstoke Reach); 9 M = 9 Mile (Revelstoke Reach); 12 M = 12 Mile (Revelstoke Reach); EA = East Arrow Park; BU = Burton Creek; LI = Lower Inonoaklin; EN = Edgewood North; ES = Edgewood South.

Treatment	Nest	Year	Species	Site	No. Eggs or Young (Host/BHCO)	Substrate	Height (m)	Elevation	Success/Fail
Control	1	2018	Alder Flycatcher	MC	3	Shrub (willow)	2.5	437	Unknown
Control	2	2018	Cedar Waxwing	MC	4	Shrub (willow)	2	438	Unknown
Control	3	2018	Cedar Waxwing	MC	5	Shrub (willow)	1.5	438	Unknown
Control	4	2018	Cedar Waxwing	MC	0	Shrub (willow)	2.5	438	Failed (Abandoned)
Control	5	2018	Cedar Waxwing	MC	0	Shrub (willow)	2.7	438	Failed (Abandoned)
Control	6	2018	Veery	MC	3	Shrub (willow)	0.3	437	Unknown
Control	7	2018	Yellow Warbler	MC	-	Shrub (willow)	3	440	Unknown
Stake	8	2018	Yellow Warbler	MC	-	Shrub (willow)	3	437	Unknown
Stake	9	2018	Yellow Warbler	MC	2/1	Shrub (willow)	1	438	Unknown
Control	10	2018	American Robin	8M	-	-	0.5	436	Probable Success
Stake	11	2018	Cedar Waxwing	8M	5	Shrub (willow)	2.2	438	Unknown
Stake	12	2018	Gadwall?	8M	9	Ground	0	440	Probable Success
Stake	13	2018	Spotted Sandpiper	8M	4	Ground	0	-	Failed (Inundated)
Control	14	2018	Unidentified Duck	8M	3	Ground	0	-	Failed (Inundated)
Control	15	2018	Unknown	8M	1	Shrub (Spiraea)	0.6	434	Unknown
Stake	16	2018	American Robin	9M	-	Shrub (willow)	0.5	437	Probable Success
Stake	17	2018	American Robin	9M	3	Tree (cottonwood)	0.8	-	Unknown
Stake	18	2018	Killdeer	9M	4	Ground	0	442	Probable Success
Stake	19	2018	Mallard	9M	5	Ground	0	436	Unknown
Control	20	2018	Yellow Warbler	9M	4	Shrub (willow)	1.5	448	Unknown
Control	21	2018	Dark-eyed Junco	12M	3	Ground (grass)	0	446	Unknown
Control	22	2018	Cedar Waxwing	EA	-	Shrub (hawthorn)	4	447	Unknown
WPW	23	2018	Chipping Sparrow	BU	4	Shrub (willow)	0.3	439	Unknown
Control	24	2018	Killdeer	BU	4	Ground	0	440	Unknown
Control	25	2018	Mallard	BU	6	Ground	0	440	Unknown
Control	26	2018	Spotted Sandpiper	BU	4	Ground	0	-	Unknown
Control	27	2018	American Robin	LI	3	Shrub	2.5	440	Probable Success
Stake	28	2018	American Robin?	LI	0	Tree (cottonwood)	1	433	Unknown
Control	29	2018	Cedar Waxwing	LI	4	Shrub (rose)	1.3	441	Unknown
Control	30	2018	Cedar Waxwing	LI	5	Shrub (rose)	2	440	Unknown
Stake	31	2018	Cedar Waxwing	LI	3	Tree (cottonwood)	2	441	Unknown
Control	32	2018	Gray Catbird	LI	4	Shrub (rose)	1.5	438	Unknown
Graminoid	33	2018	Killdeer	LI	4	Ground	0	433	Failed (Inundated)
Control	34	2018	Song Sparrow	LI	4	Shrub (rose)	1	436	Probable Success
Control	35	2018	Willow Flycatcher	LI	4	Shrub (salmonberry)	0.8	435	Unknown
Stake	36	2018	Unknown	LI	-	Tree (cottonwood)	3	-	Unknown
Control	37	2018	Swainson's Thrush?	EN	0	Shrub (cottonwood)	1	435	Failed
Control	38	2018	Swainson's Thrush	EN	1	Shrub (cottonwood)	2	435	Failed
Control	39	2018	Spotted Sandpiper	EN	4	Ground	0	442	Unknown
Control	40	2017	Chipping Sparrow	ES	1	Tree (pine)	0.4	441	Failed

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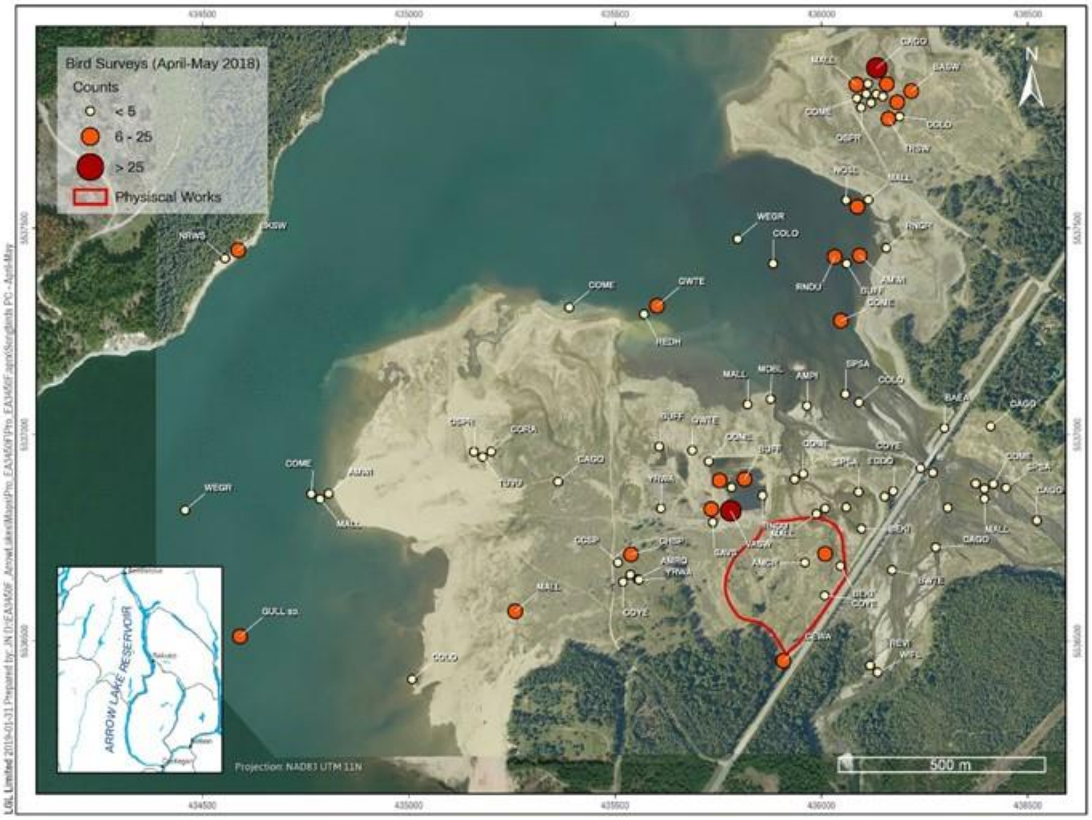
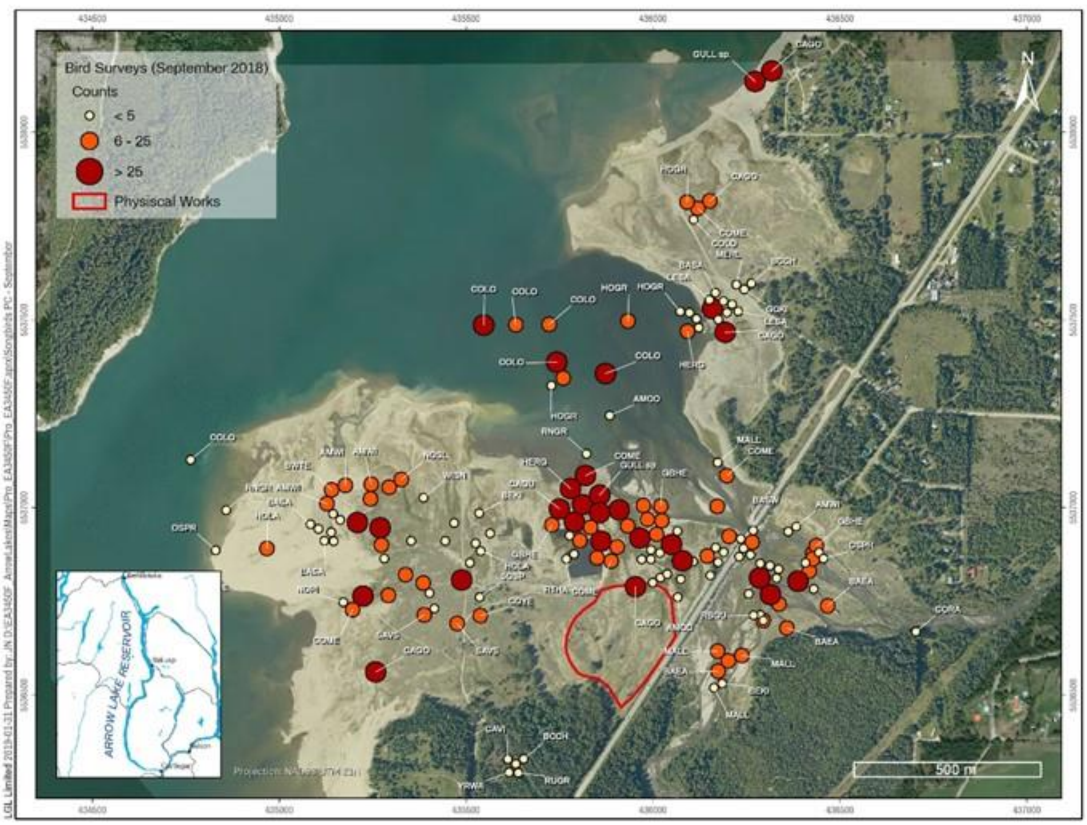
Appendix L: Distribution of bird species using the Burton Creek wildlife physical works location (red polygon) and surrounding areas in April/May 2018 (top figure), August 2018 (middle figure), and September 2018 (bottom figure).





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