Columbia River Project Water Use Plan

KINBASKET AND ARROW LAKES RESERVOIR

Reference: CLBMON-11B1

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

Study Period: 2011

LGL Limited
environmental research associates
Sidney, BC

April 2012

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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




Annual Report – 2011

Prepared for

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

EXECUTIVE SUMMARY

CLBMON-11B1, initiated in 2009, is a long-term wildlife monitoring project that aims to assess the efficacy of revegetation prescriptions (i.e., CLBWORKS-2) in enhancing the suitability of habitats in the drawdown zone of Arrow Lakes Reservoir for wildlife, and to develop a minimum of three wildlife enhancement prescriptions that can be implemented in the drawdown zone to further improve habitat suitability. The focal species groups selected for this study are songbirds, arthropods and mammals (ungulates). In addition to studying these groups, bats were incorporated into the 2010 sampling program because of the known relationships between bats, wetland and riparian habitat, and arthropods, which are their primary food source. In 2011 we sampled the same suite of wildlife that was sampled in 2010. Sampling occurred at control, treatment, and reference sites. Control sites are untreated (i.e., not revegetated) areas of the drawdown zone, treatment sites are areas where revegetation prescriptions have been applied, and reference sites are non-drawdown zone (i.e., upland habitats) that are monitored to document regional and natural variation in the taxa being studied.

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

The revegetation prescriptions applied in the drawdown zone are likely to affect prey populations (i.e., terrestrial and aerial arthropods) before they affect the predators of those arthropods (songbirds and bats). The direction and magnitude of those changes in arthropod populations will be tracked over time and will serve as a metric to assess the efficacy of each revegetation prescription applied in the drawdown zone. Specific revegetation prescriptions (live stakes) may increase the volume of ungulate browse in the drawdown zone, which is why ungulates are included in the long-term monitoring program.

In general there does not appear to be a strong relationship between the biomass of arthropods or the relative abundance of songbirds and revegetation prescriptions applied in the drawdown zone. There are distinct groupings of both arthropods and songbirds that partition along an environmental gradient representing the drawdown zone and adjacent upland habitats and these groupings were consistent between 2010 and 2011. The inherent natural variation associated with songbirds and arthropods and the relatively short time since the revegetation prescriptions have been applied is likely contributing to the lack of observed patters. More time is required to assess how species richness, biomass, and relative abundance change as a result of the implementation of the revegetation prescriptions.

The data suggest that songbirds and arthropods are likely suitable indicators to assess changes in habitat quality induced by the revegetation prescriptions, but more time needs to pass before those changes can be measured. This is based on the persistence of distinct drawdown zone and upland songbird and arthropod communities and on the relationships between songbirds and their arthropod prey. Although stochastic events appear to be affecting the biomass of arthropods (e.g., wind or rain events may have affected the total catch of arthropods in 2011), a temporal data set consisting of multiple years should provide a smoothing effect and an indication of how arthropod biomass is changing and whether that change can be correlated to revegetated areas.

Ungulate use of the drawdown zone occurs, but does not appear to be related directly to the revegetated areas. However, this is based on one or two aerial surveys per year in 2010 and 2011, which may not be representative of the actual use of the drawdown zone by ungulates. To resolve this, pellet plots were installed in 2011. These plots should be counted and cleared in 2012 and those data should provide a better indication of the use of the drawdown zone by ungulates, and more specifically, whether revegetated areas are used differently than controls.

Monitoring the use of the drawdown zone by bats has resulted in the documentation of 10 species of bat in various locations in mid- and lower Arrow Lakes Reservoir. In 2011 the provincially blue-listed Townsend's big-eared bat (*Corynorhinus townsendii*) was documented from Edgewood North. The relationship between bats and revegetation prescriptions has been difficult to assess, mainly because the light traps we have been using sample a relatively small area and the efficacy of those traps is affected by the amount of light, wind, and rain. We will continue to monitor the distribution of bats in the drawdown zone while refining our night-flying insect trapping methods.

The relationship between the effectiveness monitoring program developed and implemented in mid- and lower Arrow Lakes Reservoir will likely need to be refined to ensure that the methods used to monitor the revegetation physical works can also be used to monitor the efficacy of proposed wildlife physical works promoted in Hawkes and Howard (2011).

The next implementation year of CLBMON-11B1 is 2013 at which time a 5-yearr summary report will be prepared to assess trends in the data collected to date and to identify any major modifications to the sampling approach being used.

The following table indicates whether the management questions associated with CLBMON-11B1 will be addressed and what type of data are required to address each question. The current status of the project (with respect to data collection, etc.) is described, and an indication of when preliminary results related to each MQ and hypothesis is provided. Text under the hypotheses indicates the approach and/or data that will be used to address each question and hypothesis. The hypotheses addressed by each MQ are indicated by bold numbers.

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

Theme and Question	Component	Hypotheses and General Approach	Will MQ be Answered?	Data Required	Current Status	Preliminary Results Expected
Revegetation, wildlife, and wildlife habitat	**CLBMON-11B**	**HA_1 HA_{1A} HA_{1B} HA_{1C} HA_{1D} HA_{1E}** HA_2 HA_{2A} HA_{2B} HA_{2C} HA_{2D} HA_3 HA_{3A} HA_{3B}				
MQ: Are the revegetation and the wildlife physical works projects effective at enhancing wildlife habitat in the drawdown zone?		Only revegetation prescriptions applied to date. Focal species groups (songbirds, arthropods and ungulates); biophysical habitat mapping; habitat suitability/capability	Yes	Time Series	2nd full year of data collected (baseline + two consecutive monitoring years)	Too early to assess trends. Likely can in Year 5 (2013)
MQ: If revegetation and the wildlife physical works projects enhance wildlife habitat in the drawdown zone, to what extent does the revegetation program and the wildlife physical works projects increase the productivity of habitat in the drawdown zone for wildlife?		Only revegetation prescriptions applied to date. Focal species groups (songbirds, arthropods and ungulates); trophic linkages; assessment of changes in relative abundance, diversity and richness over time relative to each group, the interactions of those groups and to the revegetation prescriptions and/or wildlife enhancement prescriptions	Yes	Time Series	See above	Too early to assess trends. Likely can in Year 5 (2013)
Revegetation and changes to productivity	**CLBMON-11B**	HA_1 HA_{1A} HA_{1B} HA_{1C} HA_{1D} HA_{1E} HA_2 HA_{2A} HA_{2B} HA_{2C} HA_{2D} HA_3 **HA_{3A}** HA_{3B}				
MQ: Are the revegetation and the wildlife physical works projects effective at enhancing wildlife habitat in the drawdown zone?		Only revegetation prescriptions applied to date. Focal species groups (songbirds, arthropods and ungulates); biophysical habitat mapping; habitat suitability/capability	Yes	Time Series	See above	Too early to assess trends. Likely can in Year 5 (2013)
Revegetation: a comparison of techniques	**CLBMON-11B**	HA_1 HA_{1A} HA_{1B} HA_{1C} HA_{1D} HA_{1E} HA_2 HA_{2A} HA_{2B} HA_{2C} HA_{2D} **HA_3** HA_{3A} HA_{3B}				
MQ: Are some methods or techniques more effective than others at enhancing wildlife habitat in the drawdown zone?		Only revegetation prescriptions applied to date and prescriptions not applied in a way that can be used to assess treatment effects across the reservoir - site-specific responses only. Generate comparisons of relative abundance, diversity and richness data obtained for each group relative to each revegetation prescription. Likely a reach-specific analysis because of lack of replication of prescriptions.	Yes	Time Series	See above	Too early to assess trends. Likely can in Year 5 (2013)
MQ: If revegetation and the wildlife physical works projects enhance wildlife habitat in the drawdown zone, to what extent does the revegetation program and the wildlife physical works projects increase the productivity of habitat in the drawdown zone for wildlife?		Only revegetation prescriptions applied to date. Focal species groups (songbirds, arthropods, ungulates); trophic linkages; assessment of changes in relative abundance, diversity, and richness over time relative to each group, the interactions of those groups, and to the revegetation prescriptions and/or wildlife enhancement prescriptions.	Yes	Time Series	See above	Too early to assess trends. Likely can in Year 5 (2013)
Physical works	**CLBMON-29B**	HA_1 HA_{1A} HA_{1B} HA_{1C} HA_{1D} HA_{1E} **HA_2 HA_{2A} HA_{2B} HA_{2C} HA_{2D}** HA_3 HA_{3A} **HA_{3B}**				
MQ: Are the revegetation and the wildlife physical works projects effective at enhancing wildlife habitat in the drawdown zone?		Not yet implemented. Focal species groups (songbirds, arthropods, ungulates); biophysical habitat mapping; habitat suitability/capability	Yes (if physical works get implemented). Will require revisions to monitoring program	Time Series	See above	Contingent on physical works implementation schedule
MQ: If revegetation and the wildlife physical works projects enhance wildlife habitat in the drawdown zone, to what extent does the revegetation program and the wildlife physical works projects increase the productivity of habitat in the drawdown zone for wildlife?		Not yet implemented. Focal species groups (songbirds, arthropods and ungulates); trophic linkages; assessment of changes in relative abundance, diversity, and richness over time relative to each group, the interactions of those groups and to the revegetation prescriptions and/or wildlife enhancement prescriptions	Yes (if physical works get implemented). Will require revisions to monitoring program	Time Series	See above	Contingent on physical works implementation schedule

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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 implementation of physical works (revegetation and habitat enhancement) in the mid-Columbia River in lieu of changing reservoir operations to help mitigate the impact of Arrow Lakes Reservoir operations on wildlife and wildlife habitat. In addition, the Consultative Committee recommended the use of monitoring to assess the effectiveness of these physical works in enhancing habitat for wildlife.

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

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

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

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

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

2.0 OBJECTIVES AND MANAGEMENT QUESTIONS

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

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

The Water Use Plan Consultative Committee provided the following direction with respect to the revegetation and wildlife physical works effectiveness monitoring program (BC Hydro 2005):

Project Description: “Seasonal wildlife surveys (point counts, nest searches, ground track counts) to document wildlife use (birds, ungulates, bears) of revegetated areas. To also include effectiveness monitoring of wildlife physical works in Arrow”.

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

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

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

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

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

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

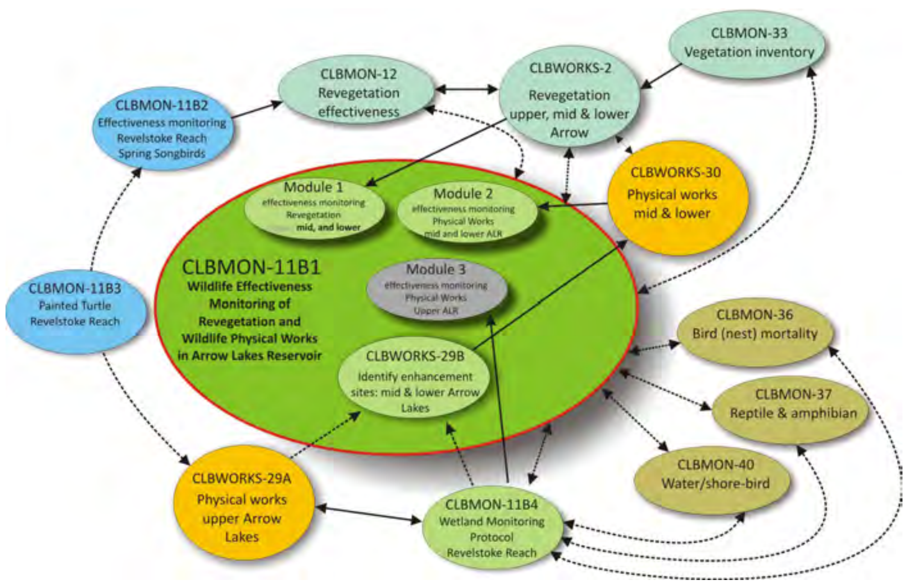


Figure 2-1: The relationship between CLBMON-11B (modules 1 and 2), all of CLBWORKS-29B, and other monitoring or physical works programs currently implemented in Arrow Lakes Reservoir. Direct linkages between relevant projects are shown as solid lines; information flow (e.g., data sharing) is indicated by dashed lines

2.1 Management Questions

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

This monitoring program will address three management questions:

1. Are the revegetation and the wildlife physical works projects effective at enhancing wildlife habitat in the drawdown zone?
2. If revegetation and the wildlife physical works projects enhance wildlife habitat in the drawdown zone, to what extent does the revegetation program and the wildlife physical works projects increase the productivity of habitat in the drawdown zone for wildlife?
3. Are some methods or techniques more effective than others at enhancing wildlife habitat in the drawdown zone?

2.2 Management Hypotheses

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

2.3 Key Water Use Decisions Affected

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

3.0 STUDY AREA

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

For CLBMON-11B1, the area of interest within Arrow Lakes Reservoir is the drawdown zone between Beaton Arm and Castlegar (Figure 3-1). For certain species groups (e.g., songbirds and terrestrial arthropods), those portions of the drawdown zone where revegetation prescriptions were applied under CLBWORKS-2 are the focal areas. For mammals (e.g., ungulates and winter furbearers), the entire drawdown zone from Revelstoke to Castlegar on both the east and west sides of the reservoir comprise the study area.

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

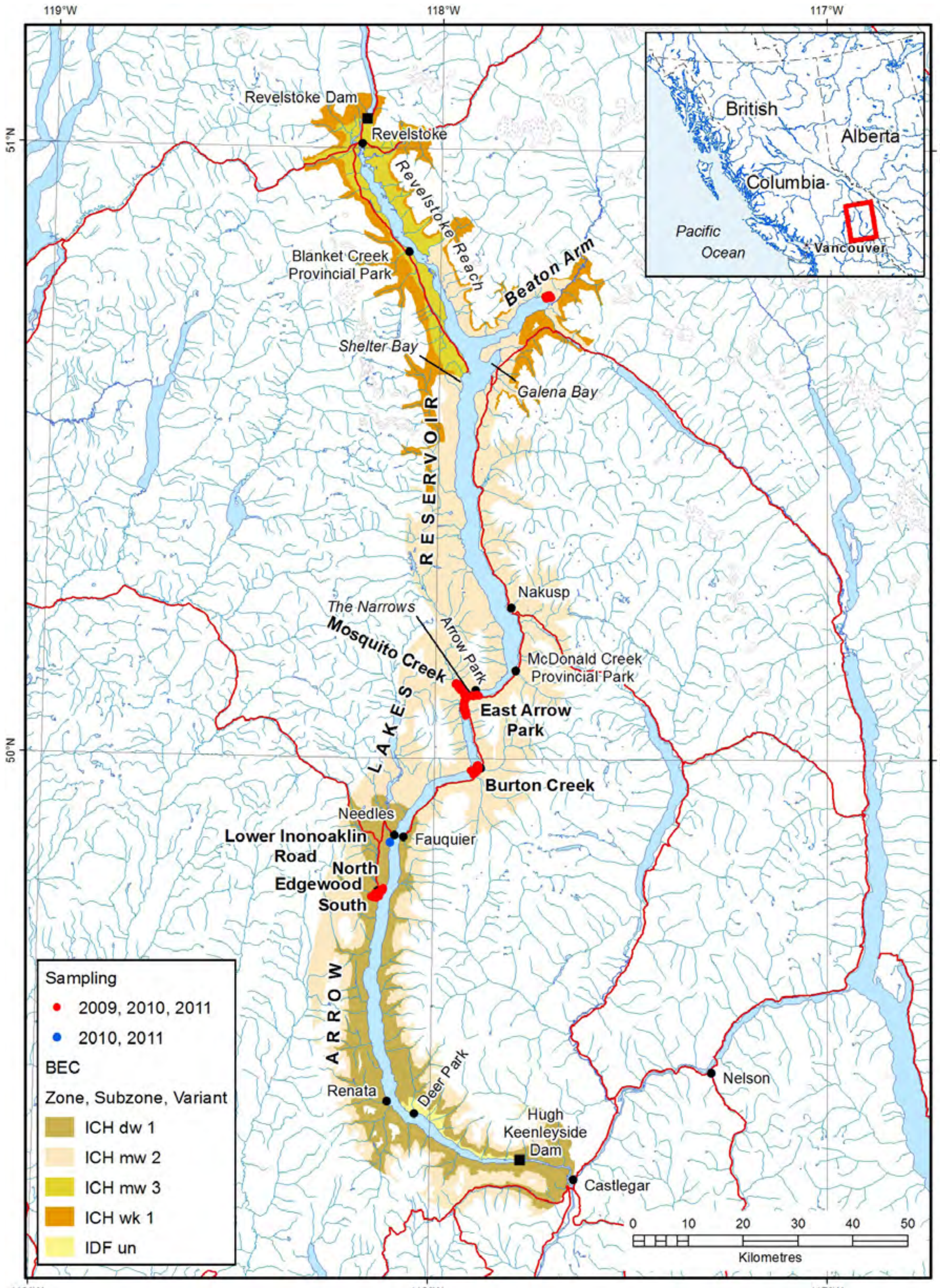


Figure 3-1: Location of Arrow Lakes Reservoir in B.C. and reaches sampled in 2011

4.0 METHODS

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

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

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

EPL: excavator-planted live stake

EPL/HPL: excavator-planted live stake and hand-planted live stake

HPL: hand-planted live stake

PS: plug seedling

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

Within each reach, sampling was conducted in control, treatment and reference sites (collectively referred to as treatments). These terms are defined as follows:

Control Site: area of the drawdown zone that was not revegetated using the revegetation prescriptions developed for CLBWORKS-2. Control polygons were placed in areas of similar elevation, topography and substrate as treatment polygons.

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

Reference Site: sampling location outside of the drawdown zone and adjacent to control and treatment sites. One of the functions of the reference sites is to allow for interpretation of naturally occurring changes in the relative abundance, diversity, richness or other metric associated with one or more of the focal groups over time. Reference sites could also be areas within the drawdown zone that represent a desired condition.

Drawdown Zone: the terrestrial portion of the reservoir that is inundated and exposed due to changing reservoir elevations.

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

Control and treatment sites were established in four broad elevation strata (modified from Keefer et al. 2009):

High elevation:	> 438 m ASL
Medium elevation:	436–438 m ASL
Low elevation:	434–436 m ASL
Lowest elevation:	< 434 m ASL

The high, medium, and low elevation strata matched those used by Keefer et al. (2009). The lowest elevation stratum was added because wildlife sampling was not constrained to elevations > 434 m ASL.

Season: In the context of CLBMON-11B1, seasons are defined as spring (April and May), early summer (June through mid-July), late summer (mid-July through mid-August) and late summer (mid-August to early September).

4.1 2011 Field Sampling Schedule

The timing of the 2011 sampling sessions (Table 4-1) was developed to ensure that sampling was conducted across the entire spring and summer season and to determine the within-year variability of arthropod and songbird assemblages that were using the drawdown zone of mid- and lower Arrow Lakes Reservoir. Sampling occurred during similar periods as in previous years.

Table 4-1: Dates and reservoir elevations of each 2011 field session (FS). A = available; NA = not available

	2011		Reservoir Elevation (m ASL)			Strata Elevation (m ASL)			
						Lowest	Low	Medium	High
FS	Start Date	End Date	Min	Max	Mean	< 434	434–436	436–438	> 438
1	May 5	May 13	430.57	430.88	430.65	A	A	A	A
2	May 19	May 25	431.49	432.38	431.87	A	A	A	A
3	June 5	June 13	434.06	435.51	434.83	NA	A	A	A
4	June 29	July 7	438.17	439.07	438.64	NA	NA	NA	A
5	July 27	August 2	439.34	439.52	439.44	NA	NA	NA	NA
6	August 20	August 24	438.67	439.07	438.88	NA	NA	NA	NA
7	September 12	September 16	437.01	437.31	437.18	NA	NA	A	A

4.2 Songbirds

Songbirds were sampled using the same methods as in 2010 (6-minute variable radius point count). In 2011 we continued to sample songbirds using the 75-m variable radius point count method, but used only songbirds documented within 30 m of the point count centre when investigating potential treatment effects. This approach has been used with great success in studies of riparian management zones in Washington State (Hawkes 2008) and for this study (Hawkes et al. 2011a). This approach yields fewer data than are typically obtained with a 75-m point count radius, but the data collected from a 30-m point count could still be used to assess temporal and spatial responses of birds to revegetation prescriptions. Detection rates can also be calculated, which allows changes in the relative abundance of songbirds over time relative to the revegetation prescriptions to be determined. Because the distance to all songbird detections was recorded, it will be possible to compare songbird data among years.

4.3 Terrestrial Arthropods

In 2011 terrestrial arthropods were sampled using the same methods as in 2010. The main methods used were pitfall traps, Malaise traps, and light traps. Netting was minimized and used strictly for incidental captures of dragonflies and butterflies. In 2010 we sampled between May and August to determine the seasonal distribution and occurrence of arthropods in the drawdown zone and to define the period during which the biomass of insects was the greatest. Based on the results obtained in 2010 we deployed Malaise and pitfall traps in May, June, and July (to coincide with songbird sampling) and light traps in August and September (to coincide with bat sampling)..

4.3.1 Pitfall Trapping

Pitfall arrays were comprised of three traps (vs. five traps used in 2010) inserted into the ground at 1-m intervals. Because each array covered 5 m^2, it was possible to replicate the number of arrays per treatment, thereby increasing the sample size associated with each treatment or control polygon. Each 5 m^2 location was randomly selected within each treatment and control polygon in a GIS by first overlaying a 5 m x 5 m grid on each treatment polygon and then randomly selecting 5 m x 5 m grids for sampling. In this way, pitfall arrays could be paired between treatment and control sites. All data collected in all arrays within a given treatment or control polygon were pooled for analyses. Maps depicting the location of pitfall traps in 2011 are provided in Appendix 10-A.

4.3.2 Malaise Traps

Malaise traps were established in control, treatment and reference locations at all reaches (except Lower Inonoaklin Road). Sample locations were selected randomly using the same method as pitfall trap site selection. Maps depicting the location of Malaise traps in 2011 are provided in Appendix 10-A.

4.3.3 Light Traps

Many moth (Lepidoptera) species are attracted to light, and are active only at night. One of the most effective ways to inventory moth species is to set up lights in the area being surveyed. The light attracts arthropods from short distances (Martin 1977). The type of light, weather conditions during the survey, and lunar conditions can all affect the quantity and variety of arthropods that are attracted to the light (Marshall et al. 1994). Lunar phase was determined before field sampling.

LUMINOC® light traps were set up in the drawdown zone at each site. Each trap was hung on a rope strung between trees or poplar stakes or was hung directly from vegetation and was used to sample moths for several consecutive nights at each site. The LUMINOC® unit has a light sensing panel and can be set to automatically turn on at dusk and run until dawn or for the desired amount of time throughout the night. Blue light was used because it has the longest wavelength range compared to ultraviolet light, and therefore has the ability to catch the greatest number of individuals from different families. Nocturnal and crepuscular moths were attracted to the light and fell into the collection container where they were killed by Vapona® (dichlorvos) strips. Traps were checked in the morning, and any moths captured were removed to limit the possibility of damage from other arthropods or rain.

4.4 Mammals

4.4.1 Terrestrial Mammals

Terrestrial mammal observations (visual sightings, wildlife signs) were documented in control, treatment and reference sites in 2011. This included recording the location of species observed in the drawdown zone, the location of pellet groups and the location of other mammal signs (e.g., bones, hair, scat). This general approach was consistent with the methods used by Hawkes et al. (2010, 2011a). We also documented the location of unique wildlife habitat features, such as mineral licks or animal dens.

The only change made to sampling in 2011 was the inclusion of circular pellet plots to further increase our understanding of the use of the drawdown zone by ungulates (see Appendix 10-B). Circular pellet plots (1.71-m radius; area = 9.2 m^2) were installed in control and treatment polygons at Burton Creek, Edgewood South, and Lower Inonoaklin Road, but not in revegetation prescription polygons. Five or six pellet plots were established per control and treatment polygon at each reach; the number of pellet plots was a function of the size of the treatment area. Pellet plots were established and cleared in June 2011 and should be checked in spring 2012.

4.4.2 Bats

Song Meter SM2BAT 192kHz Stereo Ultrasonic Recorder units (Wildlife Acoustics, Inc.; Figure 4-1) were used between August 20 to 26, 2011 to record bats feeding in the drawdown zone at six sites. Each bat detector was programmed to record between 7:30 p.m. (just prior to sunset) and 1:00 a.m. and then again from 5:00 a.m. (approximately one hour before sunrise) to 6:00 a.m. Each unit was intended to sample at least two post-sunset and pre-sunrise events, but battery life may have reduced total sampling time at some reaches while others were sampled for longer periods (e.g., Edgewood North was sampled for nearly three full cycles). At Edgewood South, Lower Inonoaklin and Burton Creek the bat detectors were situated in or angled toward a lives take treatment (EPL, EPL/HPL, or HPL) prescription. The live stake area at Edgewood North could not be accessed due to the elevation of the reservoir, but a bat detector was placed ~150 m away and was angled toward a live stake treatment. At Mosquito Creek, one bat detector was deployed to document activity over the drawdown zone along the creek. At Beaton Arm, one unit was positioned near one of the beaver ponds but was angled out to record activity over the drawdown zone. Light traps were deployed to sample arthropod activity during the same period the bat detectors were recording at each site (see Section 4.3.3).

Figure 4-1: Example of a typical Song Meter SM2BAT unit set-up on an elevated feature with the microphone aimed in the direction of the desired habitat

Bat detectors began recording at 7:30 p.m., as the sun began to set, and continued until 1:00 a.m. Within this time frame, the sun's elevation below the horizon still influences light levels until it reaches an angle lower than -18°. The period just before darkness is called astronomical twilight, when the sun's angle below the horizon is between -12° and -18°, which occurred at approximately 9:45 p.m. during the sampling period. We called the period from sunset to astronomical twilight "Evening Twilight", and the period of darkness from 9:45 p.m. to 1:00 a.m. "Night". The final period, from 5:00 a.m. to 6:00 a.m., was called "Morning Twilight".

4.4.3 Winter Mammal Surveys

Winter ungulate surveys were conducted over two days in 2012 (February 6 and 7). Surveys were conducted using a Bell 407 C-FAVI helicopter. Survey speed and height varied depending on topography, vegetation cover and the need to avoid obstacles (e.g., power lines). When surveying for mammals, air speed averaged 80 to 90 km/h, and height above ground varied from ~150 to 170 m. One navigator and two observers were used during each survey. The navigator sat in the front left position (and also recorded animal observations) and the two observers sat in the rear left and right positions. During the survey, we flew approximately 200 m upslope from the drawdown zone so that the left rear observer could see animals and their sign in the drawdown zone and in the habitats immediately adjacent to the drawdown zone. The right rear observer recorded animals and their sign in habitats upslope of the drawdown zone to identify important habitats adjacent to the drawdown zone. In general, a 400 to 500-m wide transect that included the drawdown zone and adjacent upland habitats was surveyed.

Several handheld GPS receivers (Garmin GPSMap 60CSx) were used to obtain a track of each flight and a UTM coordinate was saved every two or three seconds. The time (to the second) of each observation was recorded, and the geographic coordinates of each observation were obtained in the office by correlating the time of the observation with the UTM coordinates in the track file. The predominant habitat type, snow cover, track density and habitat suitability (subjective) was recorded for each observation. A distinction was made between live animal observations and animal sign, and between observations made in the drawdown zone and in upland habitats. When animals were observed, they were counted and assigned to an age class (adult, juvenile, or unknown) and sex class (male, female, or unknown). Track density was assigned as low (one set of tracks), moderate (several sets of tracks), or high (numerous sets of tracks). Habitat value was assessed (subjectively) as high, moderate, or low.

4.5 Data Analyses

There are 14 hypotheses that can be grouped into four broad themes. In general, data analyses performed in 2011 were the same as those in 2009 and 2010 (Hawkes et al. 2010, 2011a). However, because 2011 represented the third year of the study, we were able to make some preliminary comparisons between years, primarily to assess the level of natural variation in songbird and arthropod communities. Most of the results reported summarize the data collected in 2011 and do not assess (in detail) temporal trends. The analyses performed in 2011 aimed to do the following:

1. continue to characterize the fauna (i.e., songbirds, arthropods, mammals, and amphibians and reptiles) in the drawdown zone of mid- and lower Arrow Lakes Reservoir;
2. compare (where possible) the relative abundance and species richness of songbirds and arthropods among the various combinations of reaches and treatments between years;
3. relate the biomass of certain orders of arthropods (those eaten by insectivorous songbirds) calculated for 2011 to the songbird species that would prey on those orders; and
4. determine if the songbird and arthropod assemblages associated with drawdown and adjacent upland habitats documented in 2009 and 2010 persisted in 2011.

Songbird data were assessed for community similarity between reaches and treatments and measures of diversity, richness, and relative abundance (detection rates) were calculated. Songbird data were assessed with boxplots, ANOVAs (tested with 99,999 permutations), Principal Coordinates Analysis (PCoA), and the computation of concordance *W*, K-means and Principal Components Analysis (PCA) (all computed in the R language (version 2.12.0). The identification of clusters of species allows an investigation of the ecological requirements that are common to the cluster rather than evaluating the ecological needs of each species individually (Legendre 2005). Kendall's coefficient of concordance *W* is a measure of the agreement among several species that are assessing a given set of *n* objects (Legendre 2005), which in this case are the treatments.

As in 2009, two different association coefficients were used to compute the similarity songbird communities between treatments and reaches: the Bray-Curtis distance (D14[2]) and the Hellinger transformation followed by Euclidian distances (D17-D1). To calculate concordance *W*, K-means and PCA, only species that occurred in at least two reaches or treatment types were included in the analyses. The *W* coefficient and K-means partitions were tested with 100,000 permutations. Species richness, relative abundance, diversity and evenness of songbirds were compared among treatment types and reaches through boxplots and one- and two-way ANOVAS (comparing metrics of richness, diversity, and similarity between reaches with 9,999 and 99,999 permutations, respectively).

4.5.1 Terrestrial Arthropods

Arthropod species richness, diversity, and community similarity were compared among treatments within each reach (Hawkes et al. 2010, 2011a). Arthropods caught in Malaise traps were generally not sorted to order or family except for those caught at Edgewood South (reference), Mosquito Creek (drawdown zone and reference) and Lower Inonoaklin Road. The relative abundance of arthropods caught at all other sites and treatments was calculated using biomass estimates and count data obtained in 2009 (which follows the approach taken in 2010).

[2] D is a distance matrix produced by the transformation of ecological data. See Legendre and Gallagher (2001).

We assumed that the orders and families of arthropods captured in 2011 were the same as those captured in 2009, and we assumed that the proportional representation of orders and families calculated in 2009 applied to the 2011 sample. Based on these two assumptions, we generated estimates for the 2011 count data using the 2011 biomass data and the 2009 count and biomass data. An example of this calculation in provided in Table 4-2. In this case, the data obtained for the order Araneae in the drawdown zone of Beaton Arm in 2009 were used to estimate the number of Araneae in the 2011 sample for the same reach and treatment. Because the 2011 biomass was 2.25 times greater than that in 2009 (1800/800 mg = 2.25), the estimated count of Araneae in 2011 and the total count of all arthropods was assumed to be 2.25 greater than that in 2009. Because we assumed that the proportion of each family/order of arthropods caught in 2011 was the same as that in 2009 (0.0058 in this case; Table 4-2), we used the following formulae to derive count estimates for the 2010 data:

$$\textbf{Family count}_{2011} = \textbf{Family count}_{2009} * (\textbf{Total biomass}_{2011}/\textbf{Total biomass}_{2009})$$

An example for Araneae in 2011 is 173 *(1800/800) = 389.25

where 173 = Araneae count 2009

1800 = 2011 biomass

800 = 2009 biomass

Table 4-2: Example of 2011 arthropod biomass calculations using 2009 data

Reach and Treatment	Name	Order	Year	Dry Weight (mg) of Total Sample	Dry Weight (mg) Araneae	% Sample	Total Count	Total/Ratio
Beaton Arm drawdown zone	Araneae	Araneae	2009	800	4.62	0.0058	173	1
Beaton Arm drawdown zone	Araneae	Araneae	2011	1800	10.40	0.0058	389.25	2.25

4.5.2 Songbirds

Songbird analyses followed those described in Hawkes et al. (2011a) with several minor changes including:

1. species richness and relative abundance were compared among years, treatment types and reaches with boxplots and ANOVAs;
2. relative abundance was computed by adding up the counts of each species over all the visits to a point count and dividing by the number of visits to the point count that year. Point counts that had no counts but that were visited on at least one occasion were included. Data from 2009 and 2010 were recomputed to be consistent with 2011; and
3. species richness was computed as the total number of species observed at a point count divided by the number of visits made to the point count to correct for sampling effort.

4.5.3 Mammals

4.5.3.1 Terrestrial mammals

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

4.5.3.2 Bats

Bat calls were first run through Wildlife Acoustics' WAC2WAV 3.0.0 software, which removes most noise segments and generates time-stamped .wav files that contain bat detections. These audio clips were then processed as a batch in SonoBat 3.01 WA (Washington) west, which uses a decision engine based on quantitative analysis from reference calls. The program classified and sorted the .wav files based on several parameters that describe the time-frequency and time-amplitude trends of each bat call. Within call sequences, only individual calls exceeding a call quality of 80 per cent and discriminant probability threshold of 90 per cent were used to generate a species-level consensus by SonoBat 3.01. Following batch processing, an output table was generated and imported into Excel for further analyses, including analysis of relative abundance of each species, site richness, activity by time period, and total number of detections. In the output table, we extracted additional bat data to include in the analyses based on recordings that had at least one potential species match but did not exceed the call quality and discriminant probability threshold standards of the processing software. Due to the unknown time of apparent battery power loss that affected some bat detector units, the total number of species-level consensus detections was used as a measure of relative abundance rather than detections per unit of time. Because the number of detections may not be correlated to the number of individuals, the metric used for relative abundance reflects bat activity and not the number of individuals. Species richness (number of bat species) was summarized by reach and treatment. The number of bat call detections relative to time of sampling (twilight, night, or morning twilight) was also assessed.

4.5.3.3 Winter mammal surveys

The density of mammals (number per linear kilometre) was calculated for each species observed. Animal observations were plotted by species and habitat type (drawdown zone or upland) and by management unit (MU). All mammal species observed were mapped to assess the distribution of mammals relative to the drawdown zone during winter. The management units were used to assess the distribution of mammals in and adjacent to Arrow Lakes Reservoir so that the diversity of species could be compared to B.C. Ministry of Environment or Columbia Basin Fish and Wildlife Compensation Program data. The distribution of management units in the study area is shown in Figure 4-2. The correlation between monitoring locations (Figure 3-1) and wildlife management units is shown in Table 4-3.

Table 4-3: Study areas sampled in 2011 (ordered from north to south in Arrow Lakes Reservoir) and BC wildlife management units

Reach (study area)	Management Unit
Beaton Arm	4-33
Mosquito Creek	4-32
East Arrow Park	4-15
Burton Creek	4-15
Lower Inonoaklin	4-14
Edgewood North	4-14
Edgewood South	4-14

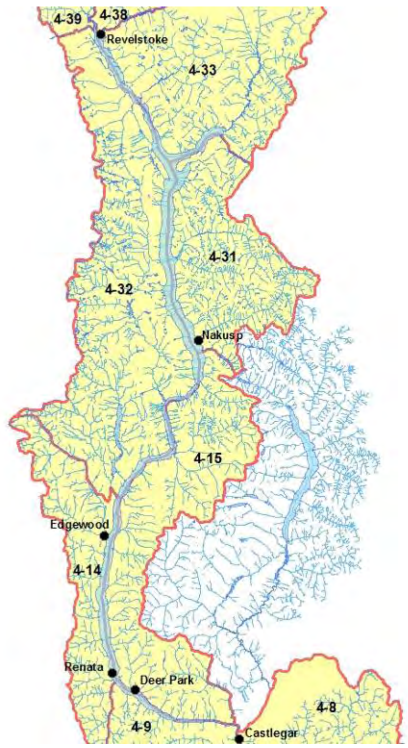


Figure 4-2: Distribution of management units adjacent to Arrow Lakes Reservoir

4.6 Habitat Enhancement Strategies

The development of wildlife physical works prescriptions was accomplished through an assessment of wildlife data collected for CLBMON-11B1 and an evaluation of where physical works projects could be feasibly be implemented. In 2010 a meeting was held to discuss several wildlife physical works projects and those projects were prioritized for prescription development. In 2011 those projects that were ranked the highest were further assessed in the field to determine the feasibility of implementation, which was based on access, current site conditions, and the presumed benefit to wildlife and wildlife habitat. Wildlife physical works descriptions and cost estimates were provided as a stand-alone report (Hawkes and Howard 2011).

5.0 RESULTS

5.1.1 Environmental Conditions

In 2011 monthly mean temperatures in the study area were similar to those recorded in 2010, but the total amount of precipitation was lower resulting in a drier summer (Figure 5-1). The influence of environmental conditions on data collected for CLBMON-11B1 will be considered in more detail in implementation Year 5 (2013). Environmental conditions during all field sessions were favourable and suitable for sampling arthropods, songbirds, bats, mammals, and amphibian and reptiles (Table 5-1).

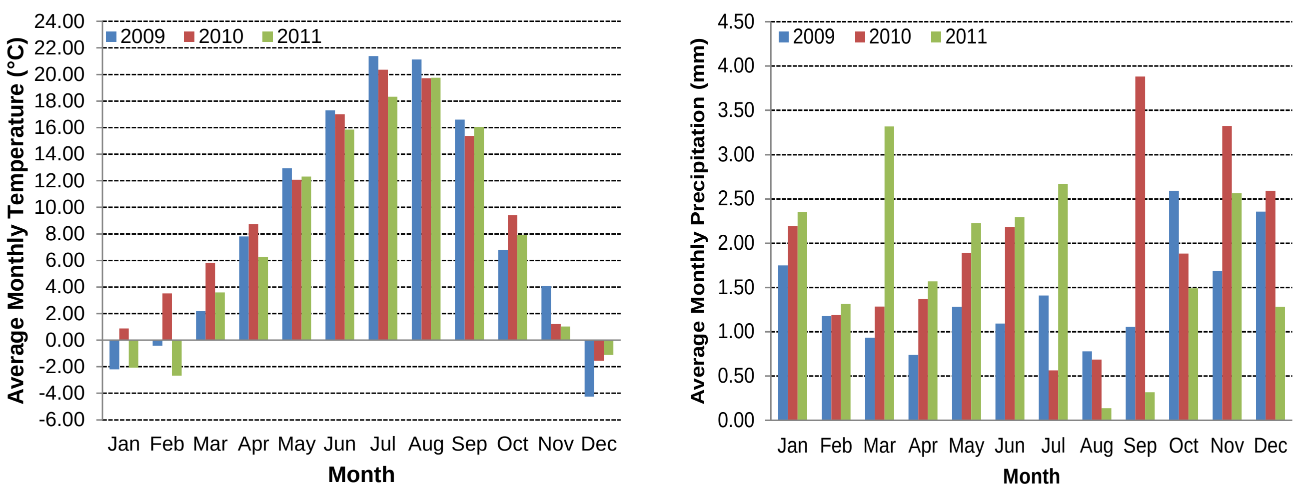


Figure 5-1: Average monthly temperatures and precipitation recorded at Nakusp and Castlegar, B.C. from January 1 through December 31, 2009, 2010, and 2011. Data obtained from http://climate.weatheroffice.ec.gc.ca/climateData/canada_e.html.

Table 5-1: Summary of environmental conditions recorded at Nakusp and Castlegar, B.C. during each field visit to the Arrow Lakes Reservoir during 2011. FS = field session; Precip is total rainfall recorded during each field session.

	2011		Daily Temperature (°C)			
FS	Start Date	End Date	Min	Max	Mean	Precip (mm)
1	May 5	May 13	1.80	24.80	11.59	17.10
2	May 19	May 25	3.95	25.05	14.57	17.35
3	June 5	June 13	7.50	28.00	15.59	35.10
4	June 29	July 7	6.95	33.65	18.87	8.40
5	July 27	August 2	8.90	31.80	19.25	0.20
6	August 20	August 24	7.95	30.40	19.87	0.00
7	September 12	September 16	7.85	32.90	19.30	3.40

5.1.2 Reservoir Conditions

The elevation of Arrow Lakes Reservoir ranged from a low of ~430.6 m ASL during field session 1 to a high of ~ 439.52 m ASL during field session 5 (Table 5-2). Arrow Lakes Reservoir reached a maximum of 439.52 m ASL on July 28, 2011, which was approximately 20 cm higher than in 2010 and 2-m higher than in 2009. The highest reservoir elevation recorded for Arrow Lakes Reservoir occurred in 2008 (439.96 m ASL on July 5; record high for the 43-year period [1968–2011]). Reservoir elevations did not impact our ability to sample songbirds, arthropods, or mammals; however, they did impact our ability to establish all pellet plots, particularly those in the drawdown zone, and they limited our access to certain reaches in late summer to sample bats.

Table 5-2: Arrow Lakes Reservoir elevations for each of the seven 2011 field sessions (FS)

	2011		Reservoir Elevation (m ASL)		
FS	**Start Date**	**End Date**	**Min**	**Max**	**Mean**
1	May 5	May 13	430.57	430.88	430.65
2	May 19	May 25	431.49	432.38	431.87
3	June 5	June 13	434.06	435.51	434.83
4	June 29	July 7	438.17	439.07	438.64
5	July 27	August 2	439.34	439.52	439.44
6	August 20	August 24	438.67	439.07	438.88
7	September 12	September 16	437.01	437.31	437.18

Reservoir elevations in 2011 were lowest during April and May (Figure 5-2), and as such, substantial areas within the drawdown zone were available for sampling. Water levels increased substantially from May to mid-July, and most of the previously available habitat was inundated. Reservoir levels began to drop in late August and decreased slightly through mid-September, which coincided with the last field session. The pattern of reservoir elevation fluctuations has been fairly consistent over the last four years (Figure 5-2).

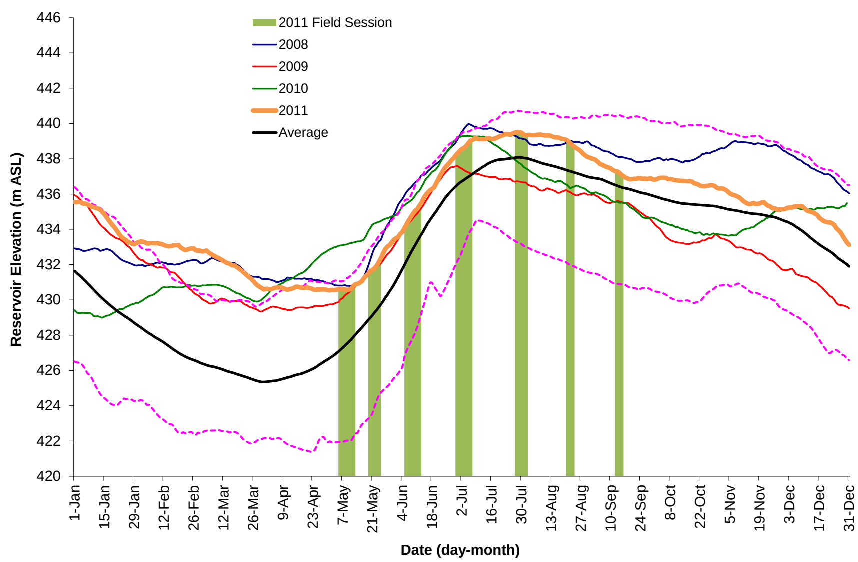


Figure 5-2: Arrow Lakes Reservoir elevations [metres above sea level (m ASL)] for 2008 to 2011. Also shown are the 10th (bottom pink line) and 90th percentiles (top pink line) for the 43-year average (1968–2011). Green shading indicates the timing of field surveys in 2011 (see Table 5-2 for dates)

5.2 Wildlife Effectiveness Monitoring

5.2.1 CLBWORKS-2 and Revegetation Effectiveness Monitoring

Revegetation prescriptions (CLBWORKS-2) were applied between 2008 and 2011 and the total area revegetated per year ranged from 2.13 ha in 2008 to 36.22 ha in 2009. The plug seedling prescription was the most commonly applied prescription (39.84 ha) followed by hand-planted live stakes (23.31 ha). All other prescriptions were either applied either over relatively small areas or in one year only. Both the plug seedling and hand-planted live stakes prescriptions were used in all reaches sampled for CLBMON-11B1. Examples of the types of revegetation prescriptions applied in the drawdown zone of Arrow Lakes Reservoir are shown in Figure 5-3.

Table 5-3: Total hectares of revegetation prescriptions applied at various sites in mid- and lower Arrow Lakes Reservoir 2008-2011. ATVS: all-terrain vehicle seeding; EPL: excavator-planted live stake; EPL/HPL: excavator-planted live stake and hand-planted live stake; HPL: hand-planted live stake; PS: plug seedling; PS-Fert: plug seedling with fertilizer application; Fert: fertilizer application only (no other revegetation prescription applied)

Year	Reach	ATVS	EPL	EPL/HPL	HPL	PS	PS-Fert	Fert	Total
2008	Burton Creek					0.16	0.06	1.64	1.87
	Nakusp					0.26			0.26
	2008 Totals					**0.42**	**0.06**	**1.64**	**2.13**
2009	Burton Creek		0.15	1.22		4.81			6.17
	Eagle Creek		1.07						1.07
	East Arrow Park	1.38			3.03	10.81			15.22
	Edgewood South			0.19		2.71			2.91
	Lower Inonoaklin		0.76	0.87		1.74			3.37
	Nakusp					7.47			7.47
	2009 Totals	**1.38**	**1.98**	**2.28**	**3.03**	**27.54**			**36.21**
2010	Burton Creek					2.1			2.1
	East Arrow Park					4.02			4.02
	Renata					5.76			5.76
	2010 Totals					**11.88**			**11.88**
2011	Beaton Arm				1.46				1.46
	Burton Creek				7.68				7.68
	East Arrow Park				5.78				5.78
	Edgewood				0.81				0.81
	Lower Inonoaklin				4.54				4.54
	2011 Totals				**20.27**				**20.27**
	4-yr totals	**1.38**	**1.98**	**2.28**	**23.3**	**39.84**	**0.06**	**1.64**	**70.5**

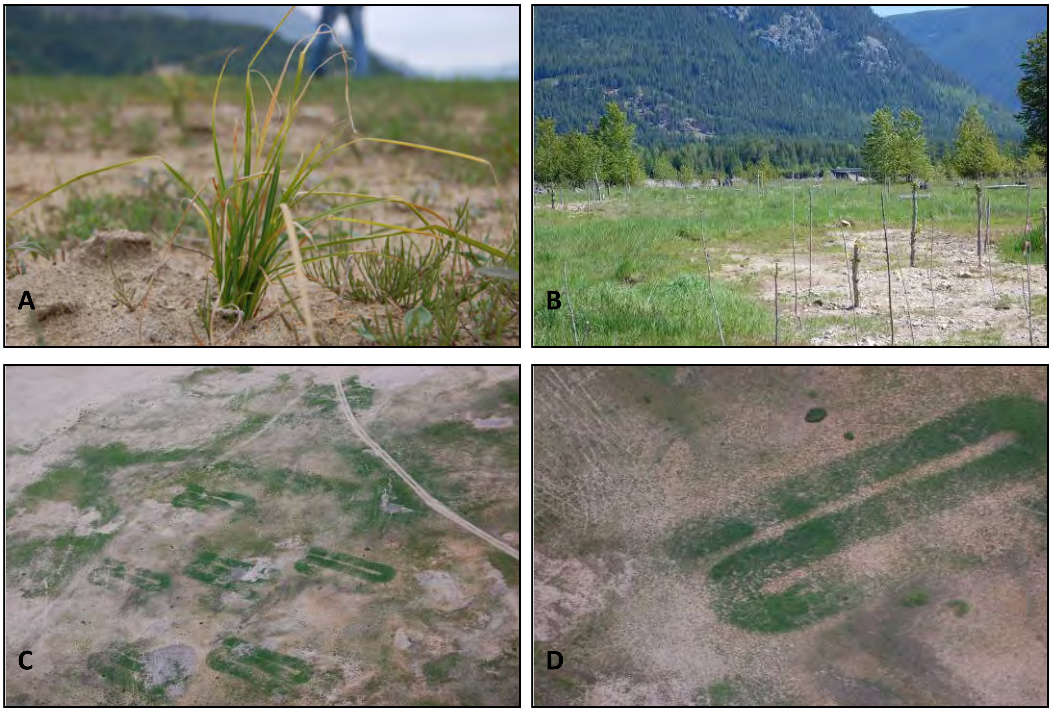


Figure 5-3: Examples of various revegetation prescriptions applied in the drawdown zone of Arrow Lakes Reservoir in 2009. A: sedge plug; B: live stakes; C: overview of fertilizer and seedling trial and Burton Creek; D: close up of fertilizer trial at Burton Creek

Although both hand-planted live stakes and plug seedling prescriptions have been applied in all reaches sampled (with the exception of Beaton Arm and Mosquito Creek), sample size was limiting because of the way the revegetation applications were implemented. For example, the total area revegetated per reach varied, not all prescriptions were applied at all reaches, and there was no within-reach replication. At present there is nothing we can do to mitigate these issues. Any assessment of treatment effects can be reach-specific only.

5.2.2 Terrestrial Arthropod Sampling

Arthropod surveys using Malaise and pitfall traps were conducted between May 20 and July 6, 2011 and night lights were set out between August 22 and September 5, 2011. Arthropod sampling was accomplished primarily through the use of Malaise and pitfall traps (see Section 4.3). Some night sampling was conducted at all reaches, but was hampered by weather (high winds and rain). Total sampling effort was 916.5 trap nights (Malaise: 153.5 nights; pitfall: 763.0 nights; Table 5-4). Sampling was mostly equally distributed among treatments; however, more sampling was done in the reference sites than in the drawdown zone at all reaches, which was directly related to a reduction in habitat availability associated with increasing reservoir levels. Most nights of trapping were conducted at Burton Creek, followed by Edgewood South and Mosquito Creek. The differences in trapping effort were related primarily to the number of treatments applied and to the total area treated.

Table 5-4: Distribution of trap nights by reach, method and treatment in the Arrow Lakes Reservoir. Sites with the same number (e.g., BU01 C and BU01 T) were paired samples. See Section 4.0 for definitions of treatments

		Trap Nights per Method		
Reach Name	**Treatment & Site**	**Malaise**	**Pitfall**	**Total**
Beaton Arm	Drawdown Zone	7.0	35.0	**42.0**
	Reference	10.5	54.0	**64.5**
Beaton Arm Total		**17.5**	**89.0**	**106.5**
Burton Creek	BU01 C	9.5	47.0	**56.5**
	BU02 C	8.0	40.0	**48.0**
	BU01 T	9.5	50.0	**59.5**
	BU02 T	8.0	40.0	**48.0**
	Reference	11.0	60.0	**71.0**
Burton Creek Total		**46.0**	**237.0**	**283.0**
East Arrow Park	EA01 C	7.5	40.0	**47.5**
	EA02 C	4.0	17.0	**21.0**
	EA01 T	7.5	40.0	**47.5**
	EA02 T	4.0	15.0	**19.0**
East Arrow Park Total		**23.0**	**112.0**	**135.0**
Edgewood North	Control	4.0	19.5	**23.5**
	Treatment	4.0	19.5	**23.5**
Edgewood South	Control	12.0	54.5	**66.5**
	Treatment	12.0	54.5	**66.5**
	Reference	12.0	58.5	**70.5**
Edgewood Total		**44.0**	**206.5**	**250.5**
Mosquito Creek	Drawdown Zone	11.0	58.5	**69.5**
	Reference	12.0	60.0	**72.0**
Mosquito Creek Total		**23.0**	**118.5**	**141.5**
Total (all reaches and treatments)		**153.5**	**763.0**	**916.5**

Malaise traps were operational for a total of 2,754.17 hours in all reaches and treatment combinations in 2011; pitfall traps were operational for a total of 13,770.13 hours (Figure 5-4). As in previous years, not all combinations of reach and treatment were sampled (Figure 5-4). Upland reference sites were not sampled at East Arrow Park and Edgewood North because of access issues and revegetation prescriptions were not applied to either Mosquito Creek or Beaton Arm. In general, a similar level of effort was expended between control, treatment, and reference sites at each reach for both Malaise and pitfall traps.

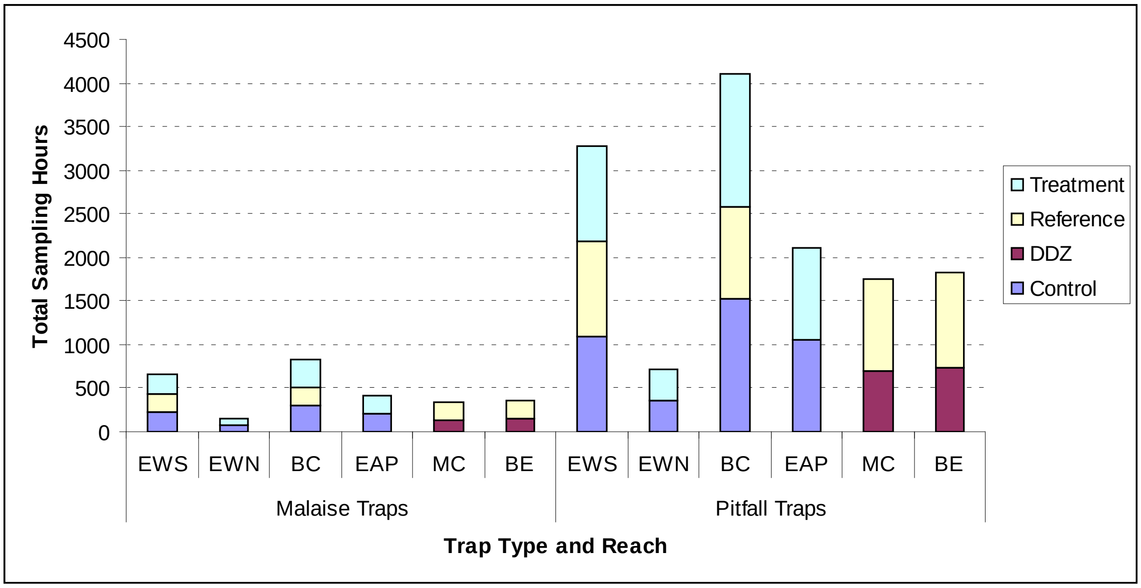


Figure 5-4: Distribution of sampling effort (total hours) in the Arrow Lakes Reservoir in 2011 using Malaise and pitfall traps in the various combinations of reach and treatment. DDZ = drawdown zone. Reaches are ordered from south to north in the reservoir: BE = Beaton Arm; BC = Burton Creek; EAP = East Arrow Park; EWN = Edgewood North; EWS = Edgewood South; MC = Mosquito Creek

5.2.3 Arthropods – Taxa per Reach and Treatment

The number of arthropod taxa (order and/or family) captured in Malaise traps and pitfall traps were used to characterize the arthropod taxa at each combination of reach and treatment sampled in 2011 (Figure 5-5). Pitfall traps almost always captured more taxa[3] than did Malaise traps, although most of the time the number of taxa captured by each trap type is similar. Given that malaise and pitfall traps target taxa with different life histories (flying versus ground-dwelling), the use of both types of traps to characterize the arthropod fauna at each reach continues to be justified and necessary.

The reference sites of Mosquito Creek were the most diverse with 82 taxa followed by the reference sites of Edgewood South (n = 77 taxa) and the control sites of Burton Creek (n = 69 taxa; Figure 5-5). As the revegetation prescriptions mature there is an expectation that the number of taxa will increase (or that biomass will increase), which needs to be tracked over time.

[3] Identification to family varied between specimens caught in Malaise and pitfall traps. Two taxonomic experts provide identifications of spiders and grasshoppers, both of which were trapped primarily in pitfall traps. Because of this the number of taxa associated with the pitfall trap data may be skewed upwards.

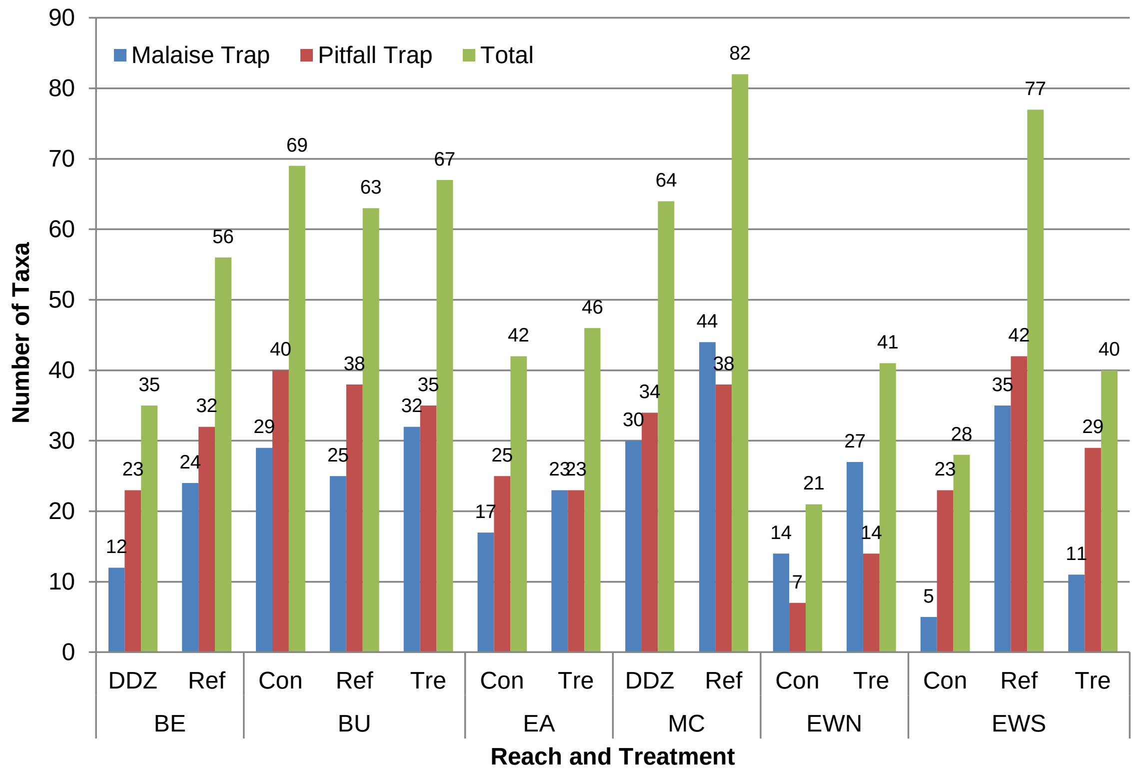


Figure 5-5: Number of taxa (orders / families) captured in malaise and pitfall traps by reach and treatment in the Arrow Lakes Reservoir (2011 data only). DDZ = drawdown zone; Ref: reference site; Con: control site; Tre: treatment site; BE: Beaton Arm; BU: Burton Creek; EA: East Arrow Park; MC: Mosquito Creek EWN: Edgewood North; EWS: Edgewood South

5.2.3.1 Species richness and relative abundance

To assess the relative abundance and species richness of arthropods at the various reaches and treatments sampled in 2011 we combined data from Malaise and pitfall traps for each reach and treatment. The relative abundance (the number caught per 24 hour period) of arthropods sampled at each reach did not vary significantly by reach or treatment (Figure 5-6). For sites where revegetation prescriptions were applied (i.e., Edgewood North and South, East Arrow Park, and Burton Creek) the relative abundance of arthropods was similar between control and treatment areas and there was little difference between control and treatment sites and upland reference sites. The relative abundance of arthropods did not differ between the drawdown zone and upland sites of Mosquito Creek and Beaton Arm. The lack of difference between control and treatment sites at reaches where revegetation prescriptions were applied suggests that there was no effect of treatment on the relative abundance of arthropods or that not enough time had passed for the treatment effect to be observed. Sample size could also be limiting.

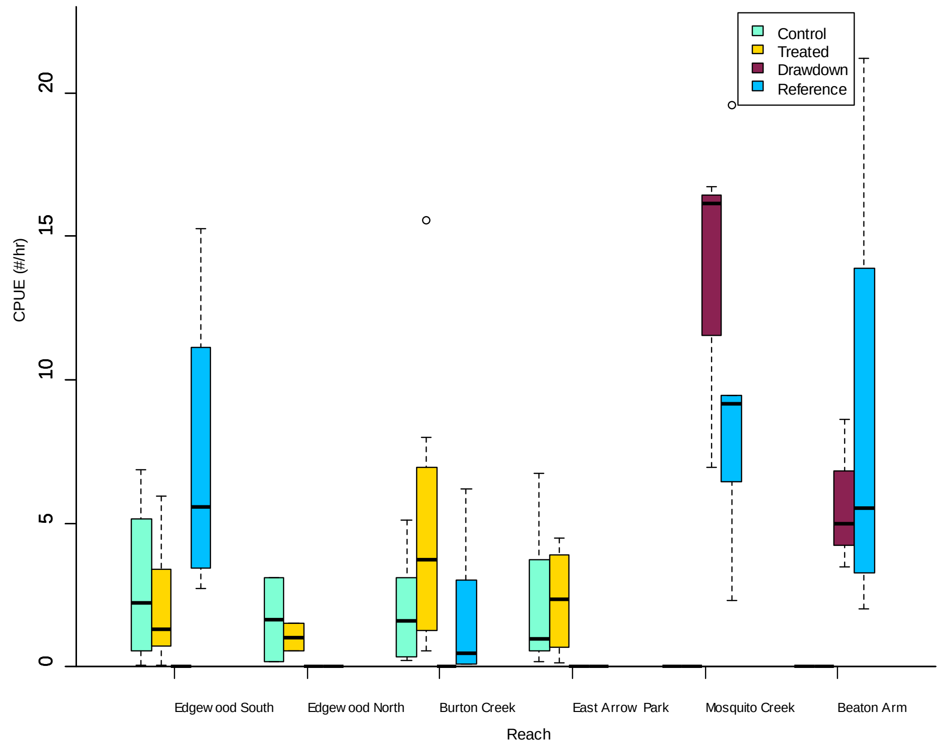


Figure 5-6: The relative abundance of arthropods (CPUE: catch per unit effort) for each reach and treatment sampled in 2011 in the Arrow Lakes Reservoir. Reaches are ordered from South to North of the reservoir

The species richness (number of orders and families) of arthropods was not statistically different among reaches or treatment types when richness was compared between reference, control and treated sites, but the interaction between the two factors was significant (F = 4.66, p = 0.02). The differences in richness were also significant between control and treatment sites only for at least one reach (reaches included were Edgewood South and North, Burton Creek, and East Arrow Park; F = 4.2, p = 0.05). The difference in species richness between reference, control and treatment sites was not significant for Burton Creek, but was significant for Edgewood South (F = 7.2, p = 0.01; Figure 5-7). This suggests that the species richness of arthropods tended to be greater in treatment than in control sites. As indicated above, the temporal component of this effectiveness monitoring program is likely limiting the observation of possible treatment effects and more time is required to assess trends in the data.

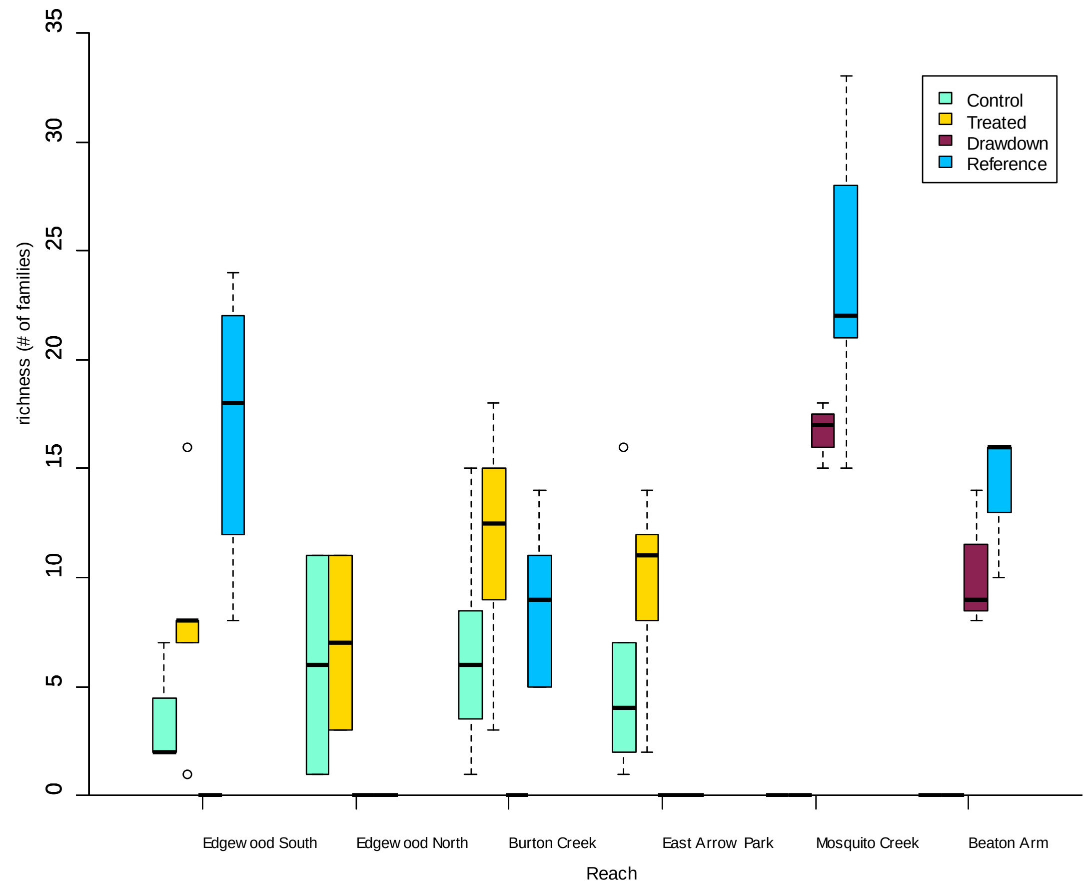


Figure 5-7: Species Richness of arthropods by reach and treatment in 2011 in the Arrow Lakes Reservoir. Reaches were ordered from south to north of the reservoir

5.2.3.2 Arthropod Biomass

Arthropod biomass (dry weight, mg/hr) varied relative to reach, treatment, and year (Figure 5-8). Overall, biomass in 2010 was greater than that in both 2009 and 2011, but there was considerable between-year variability. In 2011 arthropod biomass was quite low across all reaches and treatments sampled with higher biomass in the drawdown zone of Beaton Arm and in all treatments at Edgewood South. Environmental conditions may have contributed to the variation in biomass associated with each year; however, ambient temperature was relatively consistent among years (Figure 5-1) and average precipitation was similar for May and June, with a substantial increase in 2011 (Figure 5-1). However, the increase associated with July 2011 was not that much higher than the average monthly rainfall recorded for June 2010 and 2011, so precipitation is unlikely to have contributed to the decrease in biomass observed in 2011. Another contributing factor is wind. The influence of wind on flying arthropods can affect how many arthropods are trapped in Malaise traps. Meteorological data from meteorological stations in the Arrow Lakes region have been requested from the BC Wildlife Management Branch and once those data are provided, we will assess whether wind likely influenced arthropod biomass.

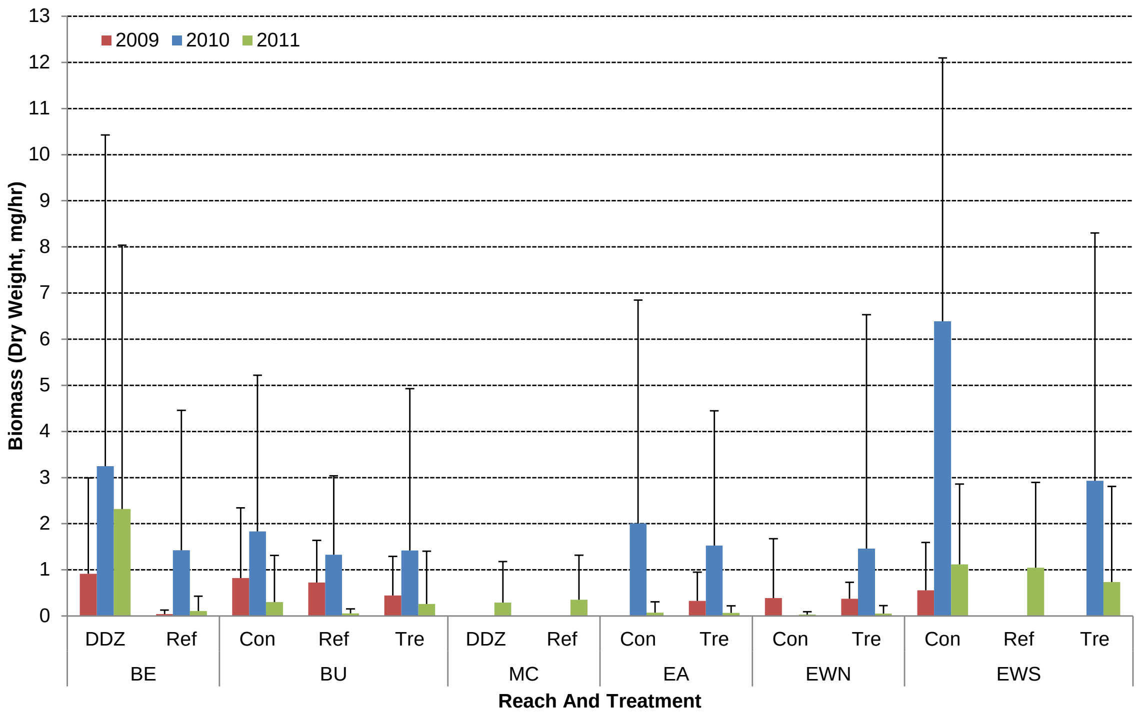


Figure 5-8: **Average arthropod biomass (+ SD) for each reach and treatment sampled in the Arrow Lakes Reservoir 2009, 2010, and 2011.** BE: Beaton Arm; BU: Burton Creek; MC: Mosquito Creek; EA: East Arrow Park; EWN: Edgewood North; EW: Edgewood South; DDZ: drawdown zone; Ref: reference site; Con: Control site; Tre = treatment site

The biomass of arthropod orders caught in Malaise trap varied relative to reach, treatment, and year (Table 5-5). However, the biomass of Diptera and Hymenoptera were generally the highest and 2010 values were higher than 2011 (which is consistent with Figure 5-8). As mentioned in the 2010 report, both Diptera and Hymenoptera appear to be suitable candidates as indicators of change associated with the revegetated areas of the drawdown zone, primarily because of their ubiquitous distribution and because they are both preyed upon by songbirds, swifts, and swallows (see Section 5.2.6.5).

Table 5-5: Biomass (dry weight, mg/hr) of arthropod orders caught in Malaise traps in the Arrow Lakes Reservoir in 2010 and 2011. LS C: live stake control, LS T: live stake treatment; PS C: plug seedling control, PS T: plug seedling treatment; Ref: reference site. Blanks indicate no captures of that order at a given combination of reach and treatment. Orders in bold represents orders most likely to preyed on by songbirds

		Burton Creek					East Arrow Park		Edgewood North		Edgewood South		
Year	**Order**	**LS C**	**LS T**	**PS C**	**PS T**	**Ref**	**PS C**	**PS T**	**PS C**	**PS T**	**LS C**	**LS T**	**Ref**
	Araneae			**0.22**	**0.56**								
	Coleoptera			**0.05**	**0.42**	**2.72**		**0.32**		**0.30**			
	Diptera	**67.24**	**116.04**	**46.91**	**43.62**	**86.44**	**129.90**	**122.23**		**71.19**	**104.21**	**108.46**	
	Hemiptera	10.01	0.67	4.78	4.45	3.81	0.94	10.84		4.15	3.36	9.43	
2010	**Hymenoptera**	**17.17**	**6.35**	**2.17**	**5.70**	**22.83**	**2.27**	**4.25**		**2.12**	**10.08**	**6.29**	
	Lepidoptera	27.18	2.34	2.28	7.50		3.21	2.47		0.91	10.08		
	Neuroptera			0.05								4.72	
	Orthoptera					**0.54**	**0.19**	**0.21**		**0.20**			
	Trichoptera	1.43											
	Araneae			**0.05**	**0.05**								
	Coleoptera			**0.01**	**0.04**	**0.10**				**0.01**			**2.22**
	Diptera	**12.27**	**22.40**	**1.14**	**4.06**	**3.03**	**3.41**	**3.84**	**0.41**	**1.26**	**13.69**	**20.40**	**44.09**
	Hemiptera	1.83	0.13	0.07	0.41	0.13	0.02	0.52		0.07	0.44	1.77	1.70
2011	**Hymenoptera**	**3.13**	**1.23**	**1.97**	**0.53**	**0.80**	**0.08**	**0.16**	**0.01**	**0.04**	**1.32**	**1.18**	**12.99**
	Lepidoptera	4.96	0.45	0.02	0.70		0.08	0.12	0.002	0.02	1.32		1.20
	Neuroptera			0.07								0.89	
	Orthoptera					**0.02**	**0.005**			**0.004**			
	Trichoptera	0.26											

5.2.3.3 Arthropod community similarity

As indicated in Hawkes et al. (2011), if the application of revegetation prescriptions in the drawdown zone affects the presence and/or abundance of arthropod taxa, community similarity might change, indicating a potential treatment effect. In 2010 the groupings of sites depended on the coefficient used. With coefficient D14, which gives the same weight to rare and abundant species, the groupings of reaches suggest that arthropod community similarity was not reach-specific. Alternatively, when more weight was given to rare species (using coefficient D17), the groupings suggested that rare species were more characteristic of the treatments (control, treated, or reference) than of the reaches, and hence, treatments clustered together rather than with the other treatments within a given reach. In 2011, a similar trend was observed when assessing community similarity using both coefficient D14 and D17 (i.e., no clustering of sites or a clustering of treatment sites; Figure 5-9). The interpretation of community similarities in 2011 suggests that arthropod communities of the drawdown zone (irrespective of treatment) are similar but different from those in the upland reference sites–a result that is not unexpected.

In 2010 we commented that arthropod communities of the treatment sites were clustering together and that there was the possibility of a treatment effect. However, the 2011 data do not support an assessment of a change in arthropod communities as a result of the application of revegetation prescriptions. This assessment is supported (in part) by the lack of changes observed in the relative abundance or species richness of arthropods sampled at the various reaches and treatments (Figure 5-6 and Figure 5-7). Once more data are collected it may be possible to detect changes in arthropod communities over time; however, natural variation or other confounding factors (e.g., climate, wind) may influence the assessment of revegetation effectiveness.

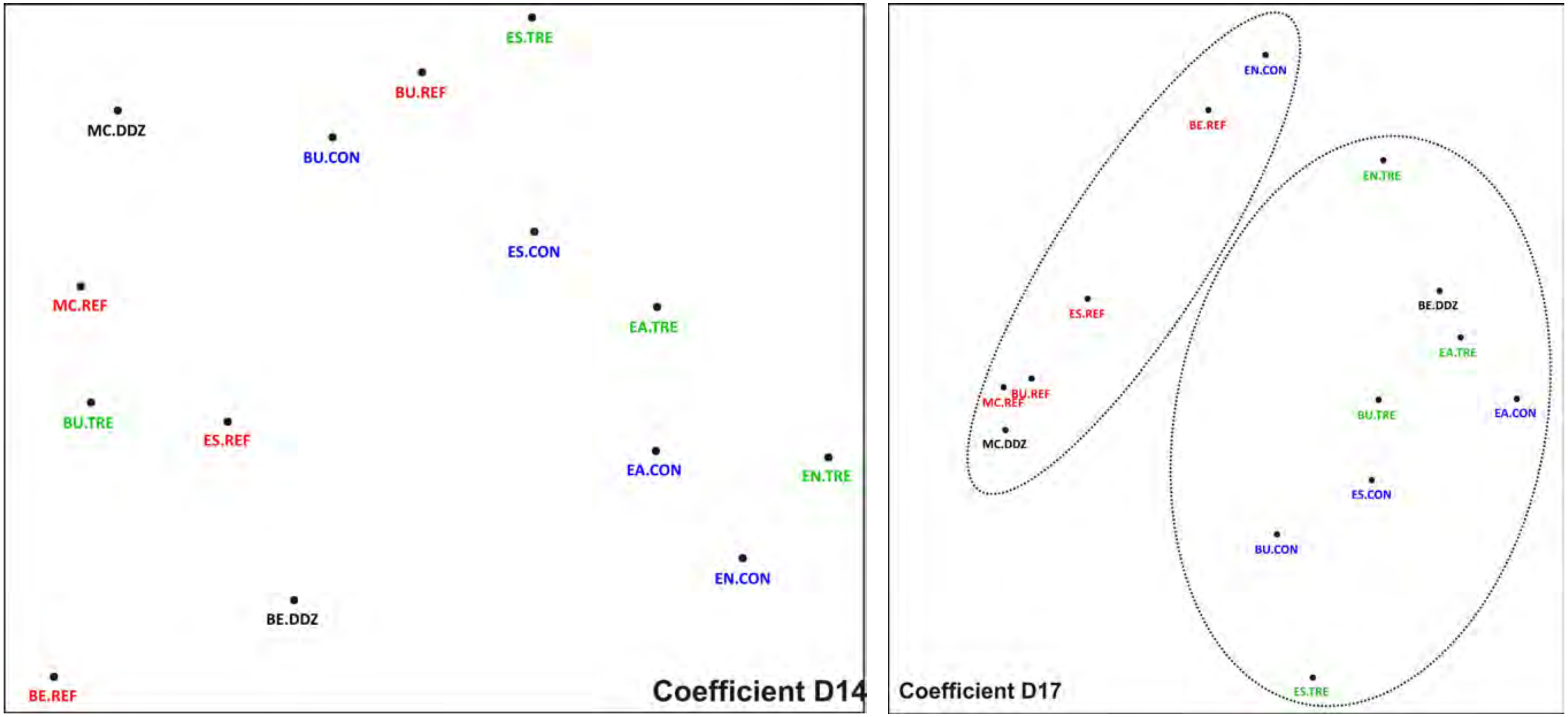


Figure 5-9: **Principal Coordinates Analysis ordination diagram showing relationships among treatments and reaches according to their similarities with respect to arthropod communities as computed by the Bray - Curtis distance (D14; same weight to rare and abundant species) and Hellinger-Euclidian distance (D17; more weight to rare species).** Axis X expresses 28 per cent and axis Y expresses 17 per cent of the variation in the data set for coefficient D14, and 26 per cent and 23.6 per cent, respectively, for coefficient D17. BU.TRE: treatment sites, Burton Creek, BU.CON: control sites, Burton Creek, BU.REF: reference sites, Burton Creek; BE.DDZ: drawdown sites, Beaton Arm, BE.REF: reference sites, Beaton Arm; EA.TRE: treatment sites, East Arrow Park, EA.CON: control sites, East Arrow Park; EN.TRE: treatment sites, Edgewood North; ES.TRE: treatment sites, Edgewood South, ES.CON: control sites, Edgewood South

5.2.3.4 Arthropod species assemblages

Most taxa of arthropods in the mid-and lower Arrow Lakes Reservoir were similar (W = 0.092, p < 0.001). Partitioning arthropod taxa into two groups was the optimal solution according to K-means, and the two groups segregated well along the X-axis of the PCA diagram (Figure 5-10). Taxa from both groups were significantly concordant in their association with specific treatments and reaches (group 1: W = 0.14, p < 0.001; group 2: W = 0.13, p < 0.001). After correction for multiple testing, one family was still significantly concordant in group 1 at α = 0.05 (Coccinellidae), and one more at α=0.1 (Acrididae) and two families (Amaurobiidae and Vespidae) were concordant with each other in group 2.

The two groups of taxa formed by the K-means partitioning can be linked to different treatments and/or reaches, suggesting a drawdown zone or upland habitat association (Figure 5-10). Taxa in group 1 were associated with the control (drawdown sites included) and treatment sites in the drawdown zone for all reaches in lower Arrow Lakes Reservoir, and with the drawdown zone of Beaton Arm. Taxa in group 2 were associated with the reference sites of Burton Creek, Edgewood South, Beaton Arm, and the drawdown zone of Mosquito Creek. The groups associated with the 2011 data are similar to those associated with the 2010 data (Hawkes et al. 2011a). Focusing future analyses on those taxa in group 1 (the drawdown zone group) may help identify treatment effects associated with the application of the revegetation prescriptions. For example, if the live stake prescription increases the amount of treed habitat in the drawdown zone, then the taxa associated with that treatment should start to resemble that of the upland grouping shown in Figure 5-10.

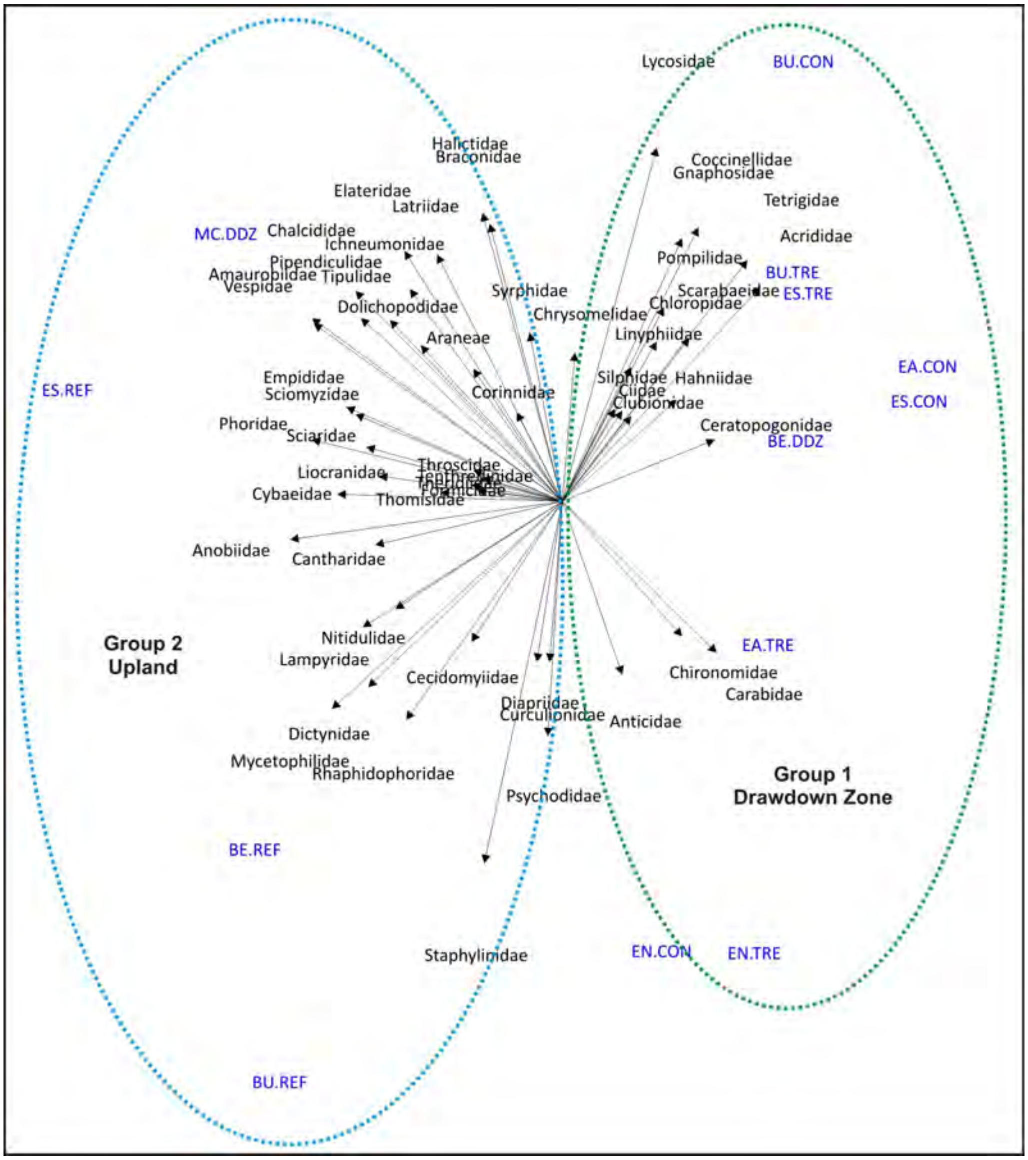


Figure 5-10: Principal Components Analysis ordination diagram with superposition of the partition results by K - means. Groupings of arthropod taxa are shown by coloured ellipses. Black vectors represent species. Axis 1 = 27 per cent and axis 2 = 22 per cent of the variation in the multi-dimensional data set. Group 1 (blue ellipse) represents the drawdown zone, and group 2 (green ellipse) represents the upland of Burton Creek. BU.TRE: treatment sites of Burton, BU.CON: control sites of Burton, BU.REF: reference sites of Burton; BE.DDZ: control sites of Beaton, BE.REF: reference sites of Beaton; EA.TRE: treatment sites of East Arrow Park, EA.CON: control sites of East Arrow Park, EA.REF: reference sites of East Arrow Park; EN.TRE: treatment sites of Edgewood North, EN.CON: control sites of Edgewood North, EN.REF: reference sites of Edgewood North; MC.DDZ: control sites of Mosquito Creek, MC.REF: Reference sites of Mosquito Creek; ES.TRE: treatment sites of Edgewood South, ES.CON: Control sites of Edgewood South, ES.REF: reference sites of Edgewood South

5.2.4 Terrestrial Arthropods – Indicator Species

In 2010 we suggested that spiders and beetles may be suitable indicators of habitat changes associated with the application of revegetation prescriptions in the drawdown zone of mid- and lower Arrow Lakes Reservoir. In 2011 we re-evaluated the utility of both spiders and beetles as indicators.

5.2.4.1 Araneae (Spiders)

In 2010 we collected spiders to determine if they were a suitable group for assessing habitat change. Spiders were collected again in 2011 to increase our understanding of the distribution of spiders in and adjacent to the drawdown zone and relative to revegetation treatments. Seventy-five species of spiders from 18 families were identified in 2011 (vs. 87 species of 17 families in 2010; Figure 5-11). Linyphiidae (sheet-web and dwarf sheet spiders) dominated the 2011 sample with 23 species, followed by Lycosidae (wolf spiders; n = 12 species) and Thomisidae (crab spiders; n = 7 species; Figure 5-11); a similar trend was reported in 2010.

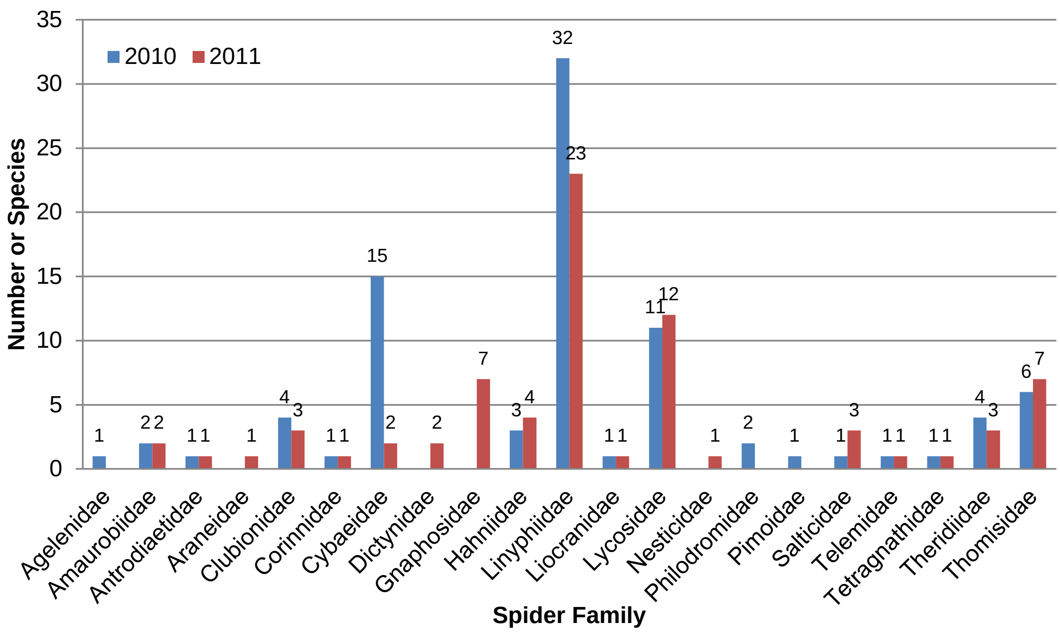


Figure 5-11: Number of spider families documented in and adjacent to the drawdown zone of mid- and lower Arrow Lakes Reservoir in 2010 and 2011. Data from all reaches and treatments pooled

The number of spider families and species varied relative to reach and treatment with most species occurring in the reference sites of Mosquito Creek and most families occurring in the reference site of Edgewood South (Figure 5-12). This trend parallels that observed for arthropods (Figure 5-5). Given the variation in the number of species and families and the fact that the number of families and/or species did not always differ between the drawdown zone and upland reference sites, using species richness of all spiders as an indicator is not currently well-supported by the data. A data set based on additional years of data may help support or refute this assessment.

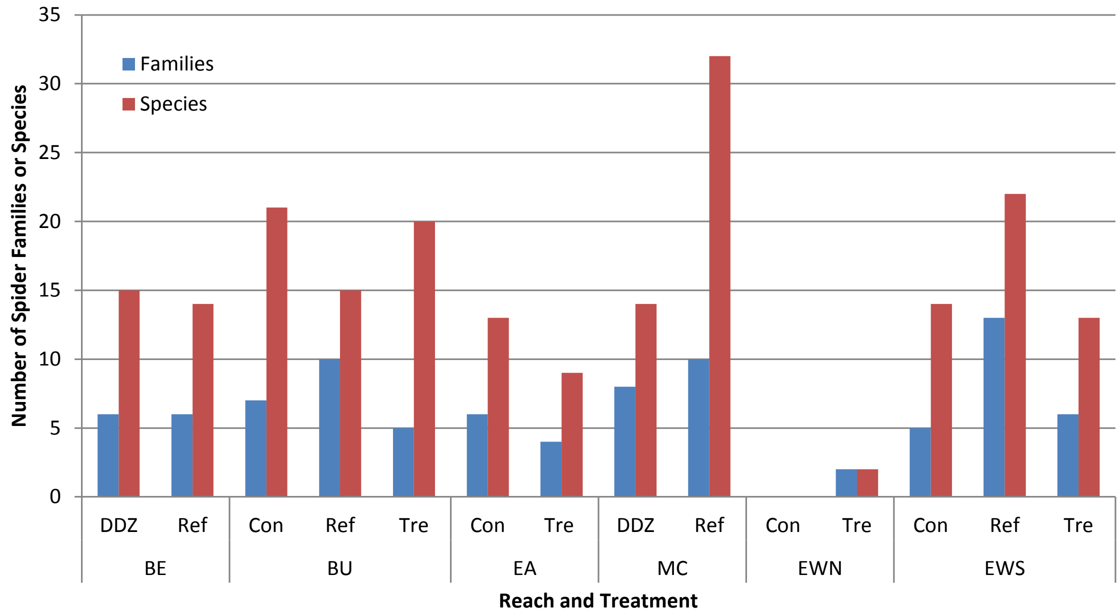


Figure 5-12: Spider families and species documented per reach and treatment in the Arrow Lakes Reservoir in 2011. BE.DDZ: control sites of Beaton, BE.REF: reference sites of Beaton; BU.TRE: treatment sites of Burton, BU.CON: control sites of Burton, BU.REF: reference sites of Burton; EA.TRE: treatment sites of East Arrow Park, EA.CON: control sites of East Arrow Park, EA.REF: reference sites of East Arrow Park; EN.TRE: treatment sites of Edgewood North, EN.CON: control sites of Edgewood North, EN.REF: reference sites of Edgewood North; MC.DDZ: control sites of Mosquito Creek, MC.REF: Reference sites of Mosquito Creek; ES.TRE: treatment sites of Edgewood South, ES.CON: Control sites of Edgewood South, ES.REF: reference sites of Edgewood South

To further assess the applicability of spiders as indicators of habitat change we assessed the distribution of unique species of Linyphiidae, Lycosidae and Thomisidae (three of the dominant families in 2010 and 2011) to determine if certain species occurred only in the drawdown zone or reference sites (Figure 5-13). There were species within each family that were unique to the drawdown or upland reference sites and these species will be tracked over time to assess how spider species composition changes relative to treatment.

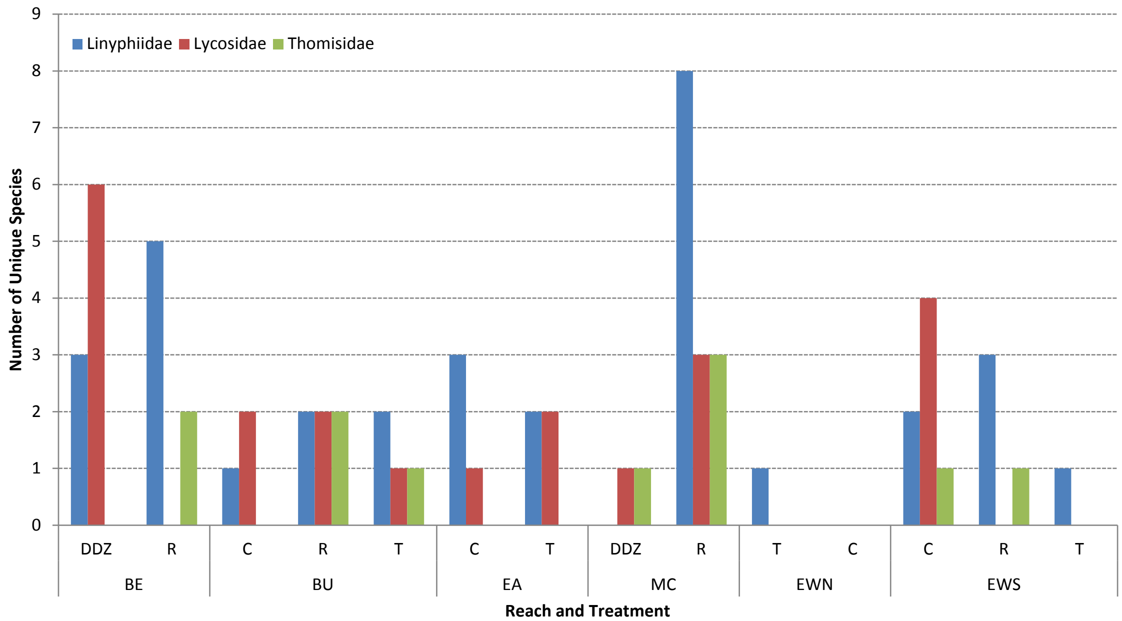


Figure 5-13: Number of unique species of the families Linyphiidae, Lycosidae, and Thomisidae associated with each reach and treatment sampled in mid- and lower Arrow Lakes Reservoir in 2011. BE.DDZ: control sites of Beaton, BE.REF: reference sites of Beaton; BU.TRE: treatment sites of Burton, BU.CON: control sites of Burton, BU.REF: reference sites of Burton; EA.TRE: treatment sites of East Arrow Park, EA.CON: control sites of East Arrow Park, EA.REF: reference sites of East Arrow Park; EN.TRE: treatment sites of Edgewood North, EN.CON: control sites of Edgewood North, EN.REF: reference sites of Edgewood North; MC.DDZ: control sites of Mosquito Creek, MC.REF: Reference sites of Mosquito Creek; ES.TRE: treatment sites of Edgewood South, ES.CON: Control sites of Edgewood South, ES.REF: reference sites of Edgewood South

Based on these results and on existing literature (see Discussion), the ability to use spiders to assess changes in habitat quality associated with revegetation of the drawdown zone continues to be high. In particular, species of sheet-web and dwarf sheet spiders (Linyphiidae) and wolf spiders (Lycosidae) have shown opposite responses to increasing vegetation cover, suggesting that the species of these two groups could serve as surrogates for all spiders. The 2011 data support the use of these families of spiders as potential indicators of habitat change.

5.2.4.2 Coleoptera (Beetles)

In 2010 we considered the suitability of ground beetles (Carabidae) as indicators of habitat change associated with the revegetation of the drawdown zone. However, after reviewing the data collected in 2011, it appears that because of the ubiquitous distribution of this family (it occurs in all reaches and treatments sampled) it is unlikely that any change in relative abundance (catch per unit effort) or species richness will be indicative of a treatment effect. For example, there does not appear to be a distinction between the catch per unit effort and treatment, particularly in those treatments where control, treatment, and reference sites have been established (Figure 5-14). It may be that formal testing of the differences in relative abundance between treatments nested within a given reach will reveal that the catch per unit effort is statistically different;

however, it remains unclear whether any statistical difference would be biologically meaningful. With an additional year of data collection we may have enough data to further assess the utility of beetles (specifically Carabidae) as a potential indicator of habitat change.

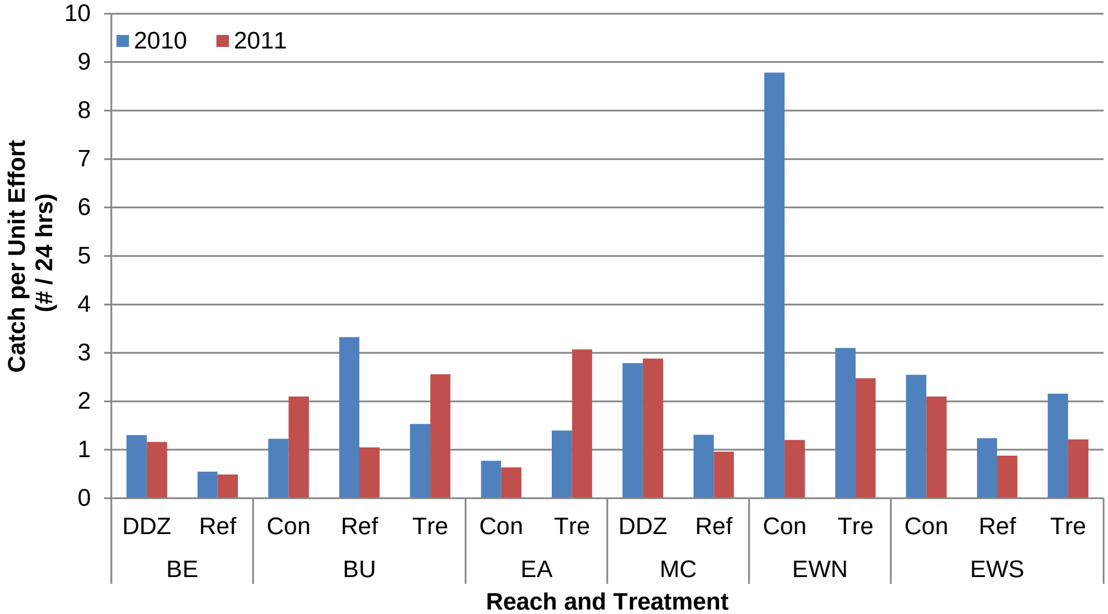


Figure 5-14: Catch per unit effort of Carabidae at each reach and treatment sampled in and adjacent to the drawdown zone of mid- and lower Arrow Lakes Reservoir in 2010 and 2011. DDZ: drawdown zone; Ref: reference site; Con: control site; Tre: treatment site; BE: Beaton Arm; BU: Burton Creek; EA: East Arrow Park; MC: Mosquito Creek; EWN: Edgewood North; EWS: Edgewood South

5.2.5 Songbirds - Overview

Songbirds were surveyed between May 6 and June 12, 2011. A total of 117 variable radius point counts were sampled in 2011 (vs. 107 in 2009 and 106 in 2010; see Appendix 10-C for maps depicting the distribution of songbirds point count locations). Each point count was visited two or three times (Table 5-6) and visits to each point count were separated by 14 to 16 days to capture within-year variability in species presence and detections. Survey effort varied by reach, and the number of point counts established per reach was a function of the area available for sampling at each reach. The highest number of point counts sampled in 2011 was in East Arrow Park, followed by Burton Creek. Revegetation prescriptions were not applied at either Mosquito Creek or Beaton Arm; therefore, point counts were established only in drawdown and reference (upland) habitats.

Table 5-6: Number of point counts sampled per reach, and type of treatment in 2011. Reaches are ordered from south to north in the Arrow Lakes Reservoir. DDZ: drawdown zone; BE: Beaton Arm; BU: Burton Creek; EA: East Arrow Park; MC: Mosquito Creek; EWN: Edgewood North; EWS: Edgewood South

Reach	Control	Treatment	DDZ	Reference	Total
BE			8	7	15
BU	7	5	6	6	24
EA	9	9	2	10	30
EN	2	4	2	2	10
ES	3	2		6	11
LI			3	6	9
MC			9	9	18
Total	**21**	**20**	**30**	**46**	**117**

A total of 5,021 detections of 121 species were made in 2011 (vs. 1,013 detections of 79 species in 2009 and 3,804 of 116 species in 2010). The increase in detections is likely a reflection of annual variation and not a reflection of a change in survey effort (as was the case in 2010). Songbirds were the most frequently encountered group, with 69 species and nine species of swifts, swallow, and hummingbirds were observed (Table 5-7). A comparison of the total number of species per group and reach between 2011 and 2009 and 2010 is provided in Appendix 10-D. The number of songbird species documented per reach varied from 49 at East Arrow Park to 34 at Edgewood North, which is consistent with data collected in 2009 and 2010.

Table 5-7: Total number of species observed and detections per bird group recorded in and adjacent to the drawdown zone in 2011. BE: Beaton Arm; BU: Burton Creek; EA: East Arrow Park; EN: Edgewood North; ES: Edgewood South; MC: Mosquito Creek. Spp: Species; Est: Estimated number of individuals. Blanks indicate no observations

2011	BE		BU		EA		EN		ES		LI		MC		Total	
Bird Group	**Spp**	**Est**	**Spp**	**Est**	**Spp**	**Est**	**Spp**	**Est**	**Spp**	**Est**	**Spp**	**Est**	**Spp**	**Est**	**Spp**	**Est**
Hawks, Eagles, Falcons and Allies	1	6	4	24	4	20	2	7	4	15	3	7	5	8	7	87
Herons, Ibises, New World Vultures and Allies	1		1	2	1	2	1	1	1	1	1		1		1	6
Kingfishers and Allies	1	3	1	3	1	5	1	1	1	1	1		1	5	1	18
Loons	1	9	2	6	0		1	7	1	2	1	2	1	6	2	32
Pheasants, Grouse, Quail and Allies	1	10	1	7	1	4	1		1		1		1	10	1	31
Pigeons and Doves	0		1	1	2	2	1	1	0		0		0		2	4
Shorebirds, Gulls, Auks and Allies	3	13	5	154	4	36	3	26	5	12	2	42	4	35	10	318
Songbirds	39	417	43	438	49	806	34	242	42	379	35	300	45	533	69	3115
Swifts and Hummingbirds	4	17	6	53	7	121	5	61	4	42	5	135	3	30	9	459
Waterfowl	4	50	8	149	7	205	8	122	6	51	8	94	7	129	14	800
Woodpeckers and Allies	4	36	4	20	4	43	0		4	14	2	11	5	27	5	151
Total Species and Detections	**59**	**561**	**76**	**857**	**80**	**1244**	**57**	**468**	**69**	**517**	**59**	**591**	**73**	**783**	**121**	**5021**

5.2.6 Songbirds, Swifts, Swallows, and Hummingbirds

The following analyses were completed only for songbirds, and swifts, swallows, and hummingbirds to (1) provide an overview of the avifauna documented from each reach and treatment sampled in 2011; (2) highlight differences in species richness, relative abundance, community similarity, and songbird assemblages in and adjacent to the drawdown zone of Arrow Lakes Reservoir; (3) compare data collected in 2009 and 2010 to those collected in 2011; and (4) continue to assess species of songbirds (i.e., swallows) that may be suitable focal species for monitoring the effectiveness of revegetation prescriptions applied in the drawdown zone of Arrow Lakes Reservoir. Maps depicting the location and distribution of songbird point count stations for each reach and treatment sampled in 2011 are provided in Section 10.3.

A total of 3,574 detections of 78 species of songbirds, swifts, swallows and hummingbirds were made in 2011. Applying the selection criteria outlined in Hawkes et al. (2010) to the bird data collected in 2011 resulted in the following datasets:

1. Birds within 75 m of the point count centre: 1, 041 detections of 64 species (n = 59 songbird species and five species of swifts, swallows and hummingbirds)
2. Birds documented within 30 m of the point count centre: 436 detection of 43 species (n = 39 songbird species and four species of swifts, swallows and hummingbirds)

5.2.6.1 Species richness and relative abundance – annual variation

To provide an indication of annual variation in songbird communities, differences in species richness by reach and treatment between years were assessed based on all songbirds documented from within 75 m of the point count centre (Figure 5-15). Species richness was corrected for sampling effort by dividing the total number of species by the total number of point counts sampled in each combination of treatment and reach. Species richness was highest in 2009 (although this was a reflection of the number of visits to each point count, which was one vs. three to six in 2010 and 2011). The number of species per point count was higher in 2011 than in 2010 and overall, differences in species richness were significant among reach and year (F = 8.1, p < 0.001 and F = 74.9, p < 0.001).

Species richness did not vary between control and treatment sites, but did between drawdown zone and reference sites (F = 145.5, p < 0.001). Species richness values associated with the drawdown zone and reference sites varied significantly by year: 2009 (F = 31.9, p < 0.001), 2010 (F = 67.1, p < 0.001), and 2011 (F = 98.9, p < 0.001), and among years for point counts in the drawdown zone (F = 21.0, p < 0.001). Overall, species richness was lowest in 2010 for all reaches and treatments.

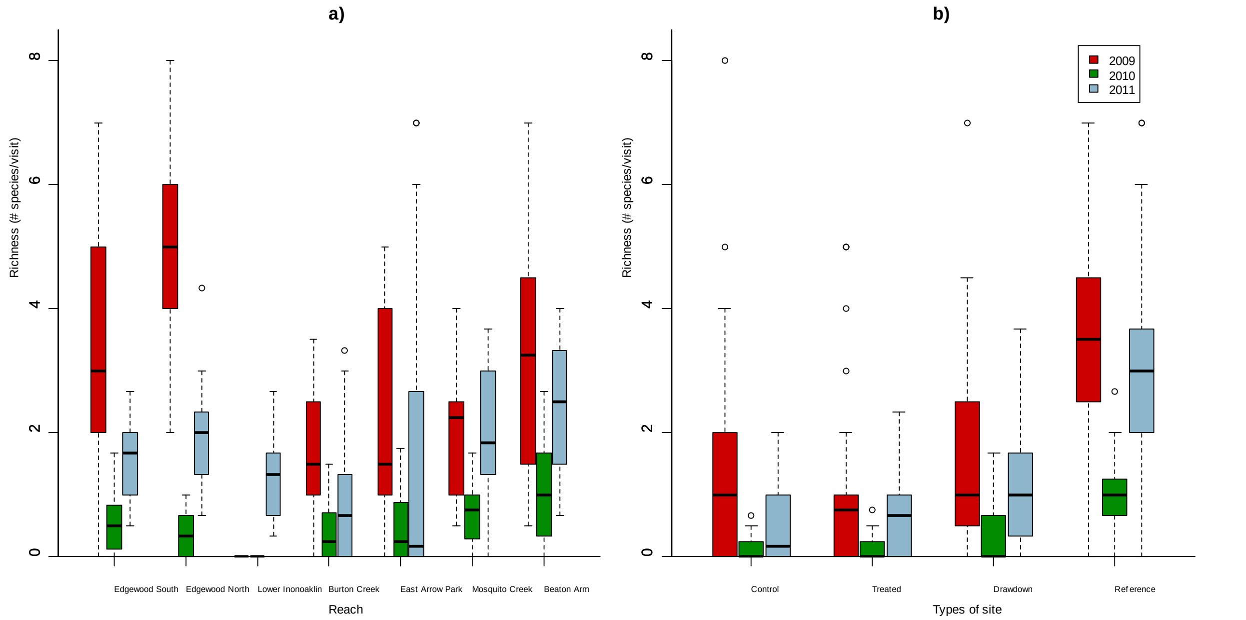


Figure 5-15: Variation in species richness of songbirds by reach (a) (data from all treatments pooled) and (b) treatment (data from all reaches pooled) Reaches are ordered from south to north in the Arrow Lakes Reservoir

The changes in relative abundance mirrored the patterns associated with species richness. In general, the relative abundance of songbirds was lowest in 2010, and was similar in 2009 and 2011 across most reaches (with the exception of Edgewood North and South; Figure 5-16). The variation in relative abundance followed a similar trend at all reaches with a decrease in relative abundance associated with 2010 followed by an increase in 2011. Differences in relative abundance were significant among reach and year (F = 4.2, p = 0.001 and F = 45.8, p < 0.001). The differences in relative abundance between control and treatment sites were not significant, but differences between sites in the drawdown zone (control, treated and drawdown sites pooled) and reference sites were significant (F = 108.3, p < 0.001), with higher relative abundance associated with the upland reference sites.

The relative abundance of songbirds in drawdown zone and upland habitats varied by year: 2009 (F = 29.7, p < 0.001), 2010 (F = 51.4, p < 0.001) and 2011 (F = 53.4, p < 0.001), and among years for the sites in the drawdown zone (F = 7.7, p < 0.001). The continued difference in relative abundance and species richness between drawdown zone and upland reference sites is not surprising given the difference in habitat structure and composition. The variation within the drawdown zone was also expected owing to the natural annual variation typically associated with the presence and abundance of songbirds in a given area.

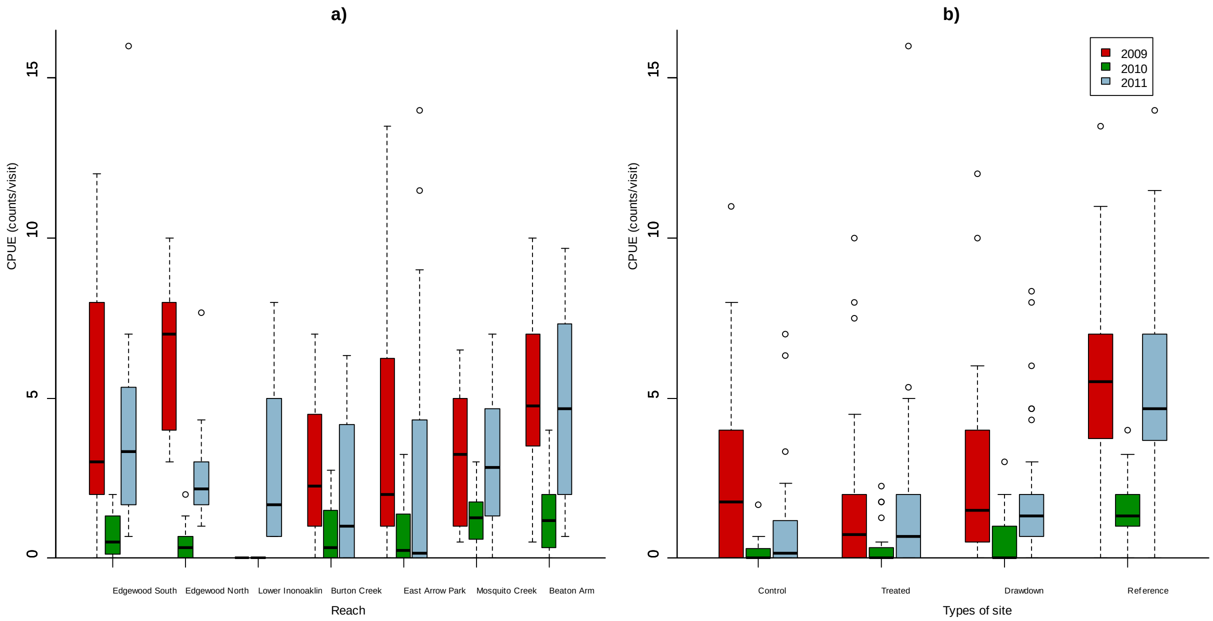


Figure 5-16: Relative abundance (counts per visit) of songbirds per reach over time (a) and per treatment over time (b). Reaches are ordered from south to north in the Arrow Lakes Reservoir

5.2.6.2 Species richness and relative abundance 2011 – treatments

Total species richness of songbirds detected within 30 m of the point count centre in 2011 was significantly higher in the reference sites compared to both control and treatment sites (Figure 5-17; $F = 88.5$, $p < 0.001$). The pattern observed in 2011 was consistent with that of 2010 (Hawkes et al., 2011a). Total species richness in control and treatment sites varied by reach and some differences were statistically significant ($F = 16.9$, $p < 0.001$). The direction of the difference in species richness between control and treatment was not consistent with higher species richness at control sites vs. treatments sites at Edgewood South and higher species richness in treatment sites vs. controls at Lower Inonoaklin Road (Figure 5-17)

At this stage of the study, more species continue to be associated with the upland reference sites and a pattern depicting differences between treatment and control sites has not yet emerged suggesting that not enough time has passed to detect possible treatment effects. The influence of natural variation on an assessment of possible treatment effects will need to be considered in Year 5 (when more detailed temporal analysis can be conducted).

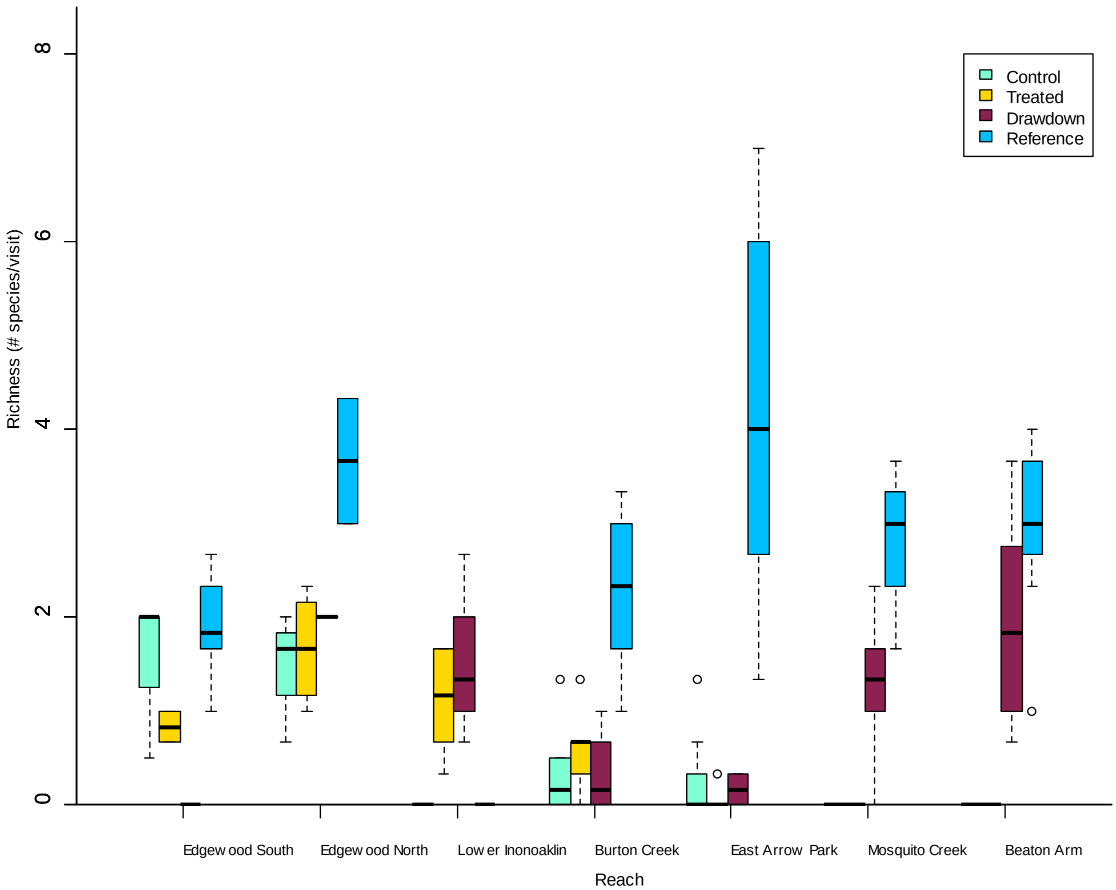


Figure 5-17: Variation in species richness of songbirds by reach and treatment in the Arrow Lakes Reservoir. Data are for 2011 only and consist of songbird observations within 30 m of the point count centre. Drawdown zone point counts were merged with control site point counts for all reaches where they occurred

The relative abundance of songbirds (number of detections per point count) was markedly higher in all reaches where treatments were applied with the exception of East Arrow Park (Figure 5-18), a pattern that was consistent with that observed in 2010. Relative abundance values were not significantly different between control and treatment sites, but they were significant between all drawdown sites and reference sites (F = 34.4, p < 0.001). Differences between reference and drawdown sites were statistically significant for all reaches except Edgewood South (Beaton Arm, F = 6.8, p = 0.03; Burton Creek, F = 9.5, p = 0.01; East Arrow Park, F = 80.0, p < 0.001; Edgewood North, F = 24.1, p = 0.01; and Mosquito Creek, F = 20.8, p < 0.001).

The relationship between revegetation prescriptions and the relative abundance (detection rate) of songbirds is not yet clear and more data are required to investigate this. However, it appears that the pattern of relative abundance observed in 2010 (with higher relative abundance in treatment vs. controls) is persisting, which could be a reflection of improved wildlife habitat quality in the drawdown zone resulting from the application of revegetation prescriptions.

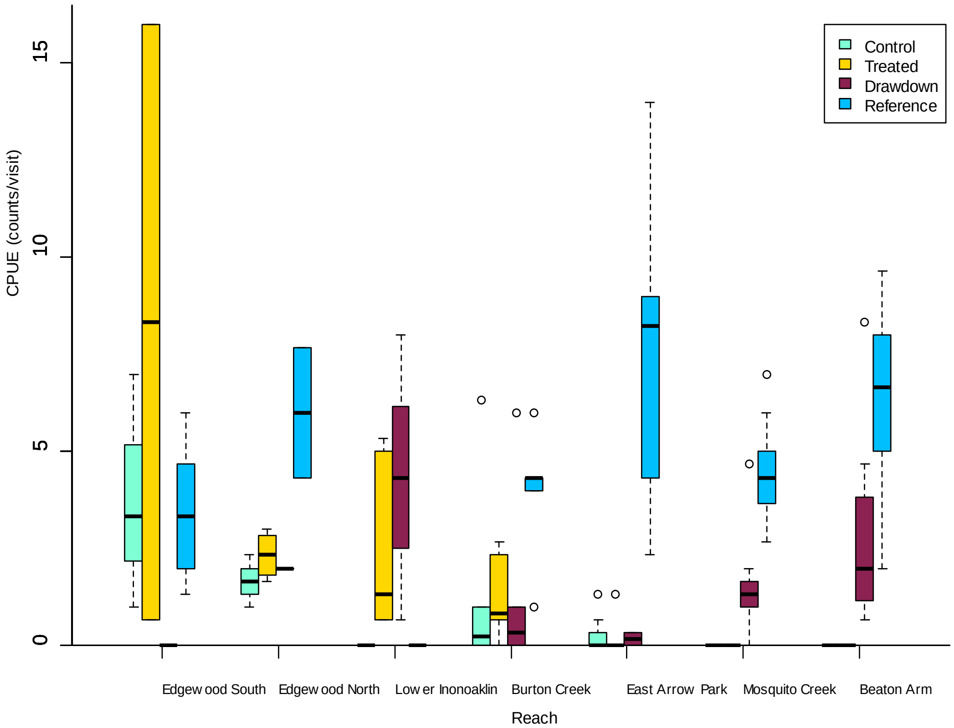


Figure 5-18: Relative abundance of songbirds by reach and treatment in the Arrow Lakes Reservoir. Drawdown zone point counts were merged with control site point counts for all reaches where they occurred. Reaches are ordered from south to north in the Arrow Lakes Reservoir

5.2.6.3 Community Similarity

The Principal Coordinates Analysis revealed the formation of three main groups of sites (i.e., reach and treatment combinations) discriminated along the X-axis by both the Bray-Curtis and Hellinger distance coefficients (Figure 5-19; results with Hellinger distance not shown). Both coefficients produced the same clustering, which suggests that rare and abundant species of songbirds had similar weight in the computation of community similarities. In 2011, reference sites continued to cluster together as they did in 2010; untreated drawdown sites of Beaton Arm and Mosquito Creek and all sites of Edgewood North also formed a cluster of sites (meaning they could be characterized by the same species of songbirds). The 2011 clustering of sites represents a shift for the control and treatment sites at Edgewood North, which were more similar to the Burton Creek and East Arrow Park controls sites in 2010 (Hawkes et al. 2011a). Burton Creek drawdown sites (control, treatment, and drawdown zone sites) clustered together and appeared more similar to the drawdown sites of Lower Inonoaklin than any other combination of reach and treatment.

Differences in songbird communities between the drawdown zone and the upland reference sites were expected given the difference in habitat composition and structure. Differences between control and treatment sites were not as apparent as they were in 2010 with the controls and treatments of reaches where treatments were applied (i.e., Edgewood North and South, Burton Creek, East Arrow Park) remaining fairly close to each other in the ordination diagram. The change from 2010 could be due to the natural variation in the songbird community or to a lack of influence of the treatments on songbird community similarity. More data are required to identify trends (if any) relative to community similarity.

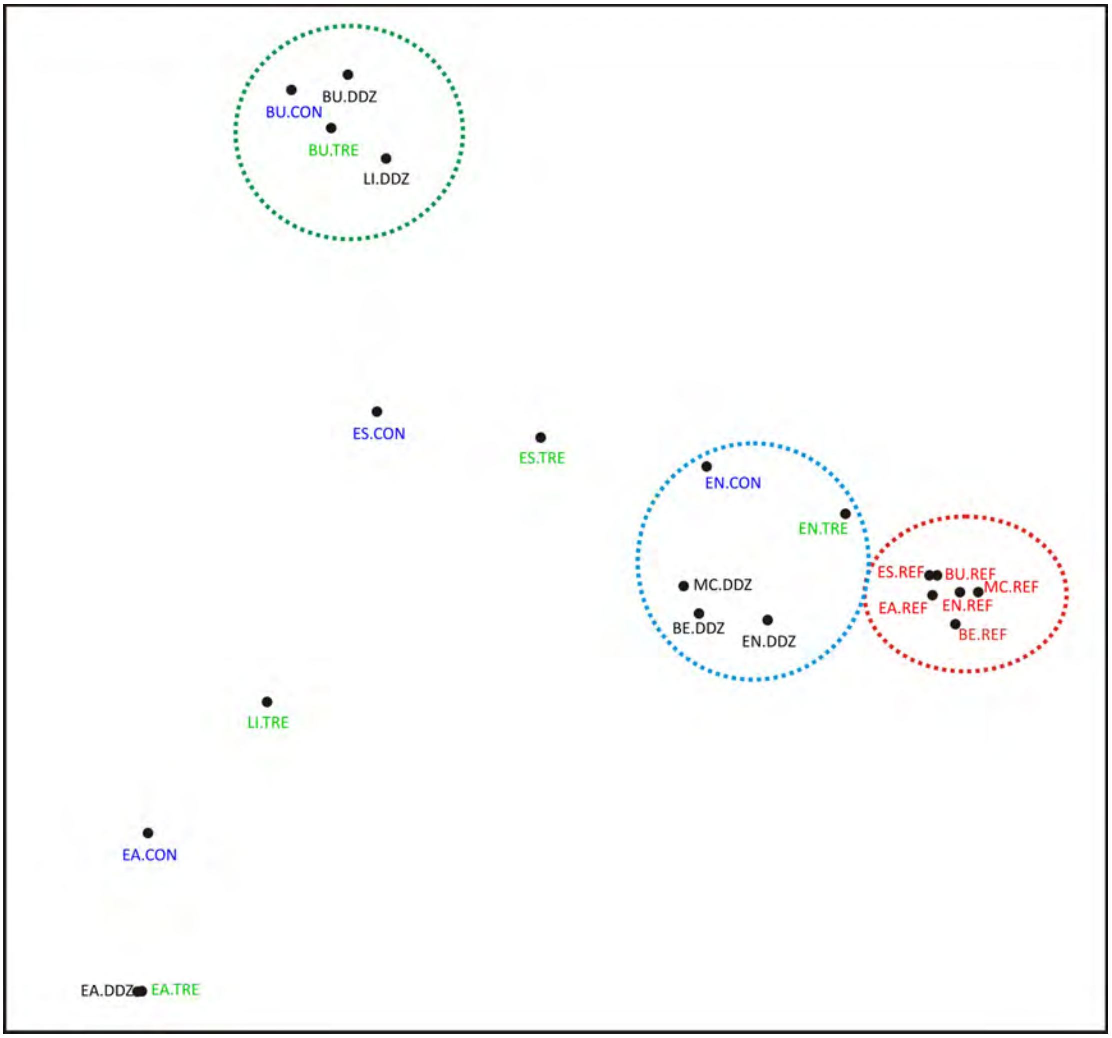


Figure 5-19: Principal Coordinate Analysis (PCoA) ordination diagram showing the relationships among types of sites and reaches according to their similarities based on songbird communities, as computed by the Bray-Curtis distance (D14). Axis X expresses 29 per cent of the variation of the data set, and axis Y, 20 per cent. BU.TRE: treatment sites of Burton, BU.CON: control sites of Burton, BU.REF: reference sites of Burton, BU.DDZ: drawdown sites of Burton; BE.DDZ: control sites of Beaton, BE.REF: reference sites of Beaton; EA.TRE: treated sites of East Arrow Park, EA.CON: control sites of East Arrow Park, EA.REF: reference sites of East Arrow Park, EA.DDZ: Drawdown sites of East Arrow Park; EN.TRE: treatment sites of Edgewood North, EN.CON: control sites of Edgewood North, EN.REF: reference sites of Edgewood North, EN.DDZ: Drawdown sites of Edgewood North; MC.DDZ: control sites of Mosquito Creek, MC.REF: reference sites of Mosquito Creek; ES.TRE: treatment sites of Edgewood South, ES.CON: control sites of Edgewood South, ES.REF: reference sites of Edgewood South; LI.TRE: treatment sites of Lower Inonoaklin, LI.DDZ: Drawdown sites of Lower Inonoaklin. Ellipses emphasize clusters of sites and do not infer statistical relationships

5.2.6.4 Songbird species assemblages

Understanding how songbirds partition themselves between the drawdown zone and upland reference sites will help determine the magnitude and direction of observed treatment effects after several years of data collection. Many species of songbirds detected in mid- and lower Arrow Lakes Reservoir were concordant (W = 0.16, p < 0.001). As in 2009 and 2010 (Hawkes et al. 2010, 2011a), a partition of species into two groups was the optimal solution according to K-means, and the two groups segregated well along the X-axis of the PCA diagram (Figure 5-20).

The two groups of species formed by the K-means partitioning can be linked to different treatments and/or reaches, thereby suggesting a riparian/drawdown zone or upland habitat association. Group 1 species were associated with drawdown zones of reaches where revegetation prescriptions were applied, while group 2 was associated with upland reference sites of all reaches and the drawdown zones of reaches where revegetation prescriptions were not applied. At least some of the species within each group were significantly concordant in their association with specific treatments and reaches (group 1, drawdown zone: W = 0.13, p = 0.014; group 2, upland: W = 0.29, p < 0.001). After correction for multiple testing, none of the species in group 1 (drawdown zone) were still significantly concordant (at α=0.05), but eight species were concordant with each other in group 2. Seven of these eight species were also concordant in 2010 (CAVI, CBCH, DEJU, GCKI, HAFL, PISI, RCKI see Appendix 10-D for an expansion of bird codes).

Species that formed both groups were slightly different between years, but some species were the same (e.g., NRWS in group 1 and RUHU, YRWA, CHSP, RBNU, etc. in group 2). The natural variation associated with songbird species presence and relative abundance may result in minor changes to the groups of songbirds that partition between drawdown zone and upland habitats; however, the persistence of several species within each group suggests that these species can be tracked over time and used to assess revegetation effectiveness.

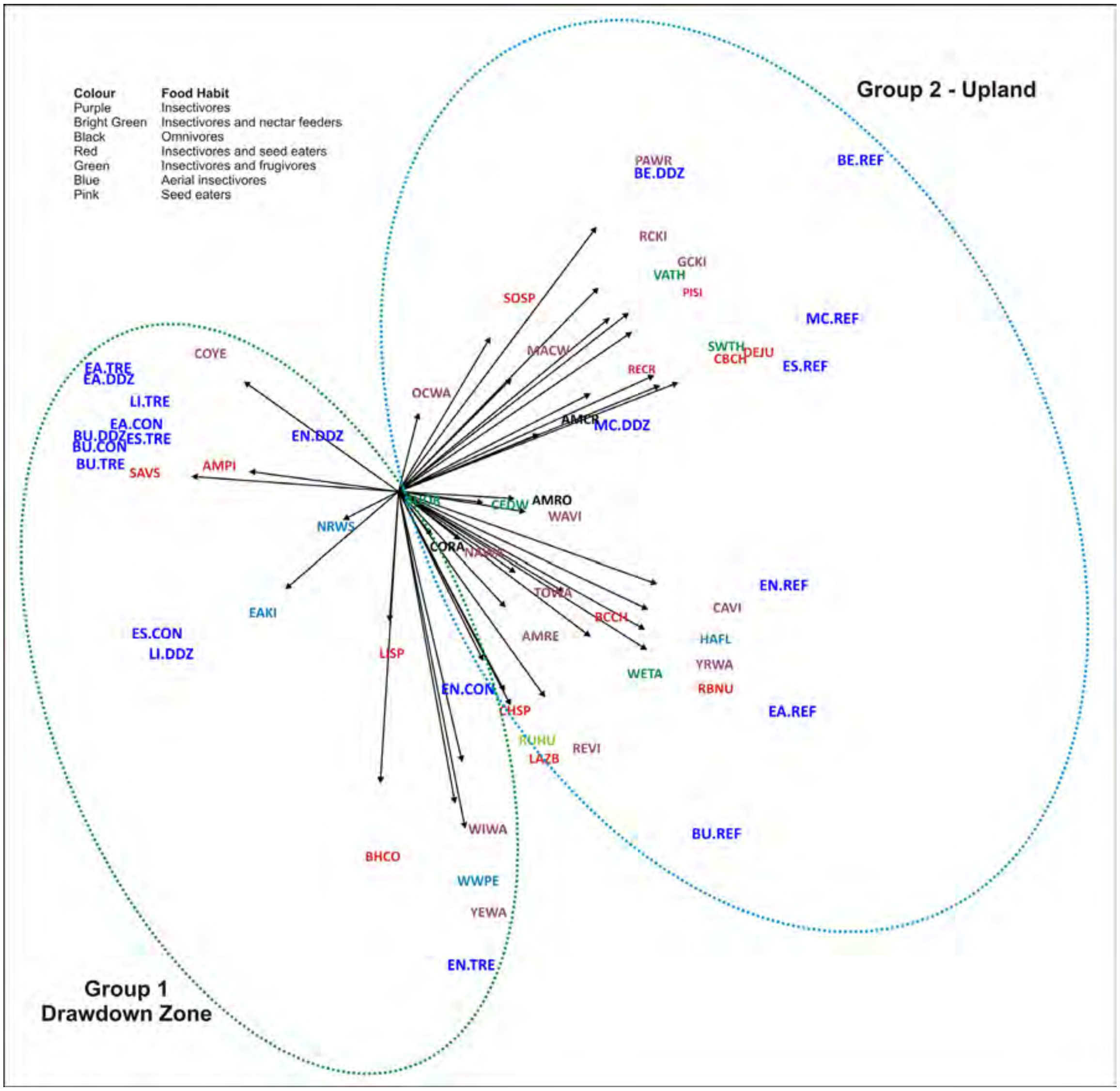


Figure 5-20: Principal Components Analysis ordination diagram with superposition of the partition results by K-means. Groups of songbirds are indicated by coloured ellipses and bird species are colour-coded by food habit. Black vectors represent species, and numbers refer to the two groups of species formed by K-means. Axis 1 = 29 per cent and axis 2 = 12 per cent of the variation in the multi-dimensional data set. Ellipses are added to emphasize groupings, not to indicate statistical relationships. BU.TRE: treatment sites of Burton, BU.CON: control sites of Burton, BU.REF: reference sites of Burton; BE.DDZ: control sites of Beaton, BE.REF: reference sites of Beaton; EA.TRE: treatment sites of East Arrow Park, EA.CON: control sites of East Arrow Park, EA.REF: reference sites of East Arrow Park; EN.TRE: treatment sites of Edgewood North, EN.CON: control sites of Edgewood North, EN.REF: reference sites of Edgewood North; MC.DDZ: control sites of Mosquito Creek, MC.REF: reference sites of Mosquito Creek; ES.TRE: treatment sites of Edgewood South, ES.CON: control sites of Edgewood South, ES.REF: reference sites of Edgewood South

5.2.6.5 Songbird food habits

Many songbird species feed on arthropods, and the relationship between arthropod biomass and songbird communities is well established. Revegetating the drawdown zone of mid- and lower Arrow Lakes Reservoir should first affect arthropod communities (as measured by changes in biomass, species richness and diversity; see Section 5.2.3). These changes should be followed by a measureable change in either the songbird communities or the relative abundance of certain species associated with the two groups identified in Figure 5-20.

Songbirds can be grouped by their food habits (Table 5-8). As in 2010, no apparent association between revegetation treatment and songbird food preference was observed (i.e., birds that feed primarily on insects were not strongly correlated with treatment sites). However, the relative abundance of 10 bird species (i.e., those in group 1 in Figure 5-20) was highest in the reaches where treatments were applied. These 10 species are insectivores, aerial insectivores, or insectivores and seed eaters; arthropods comprise all or a substantial component of each of these species diet (Table 5-8).

Table 5-8: List of songbird species per food group[1] in 2011. Codes in bold represent species associated with the drawdown zone of reaches where revegetation treatments were applied. Species codes are defined in Appendix 10-D

Food Group	Species Code
Aerial Insectivores	**EAKI**, HAFL, **NRWS, WWPE**
Insectivores and Frugivores	BUOR, CEDW, SWTH, VATH, WETA
Insectivores and Nectar feeders	RUHU
Insectivores and Seed eaters	**AMPI**, BCCH, **BHCO**, CBCH, CHSP, DEJU, LAZB, **LISP**, RBNU, **SAVS**, SOSP
Insectivores	AMRE, CAVI, **COYE**, GCKI, MACW, NAWA, OCWA, PAWR, RCKI, REVI, TOWA, WAVI, **WIWA**, **YEWA**, YRWA
Omnivores	AMCR, AMRO, CORA
Seed eaters	PISI, RECR

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

Certain species of songbirds (including the 10 species that comprise group 1 in Figure 5-20) could be correlated with one or more orders of arthropods sampled in 2011 (Figure 5-21). The relative abundance of Northern Rough-winged Swallow (NRWS), Western Wood-Pewee (WWPE), Yellow Warbler (YEWA), Wilson's Warbler (WIWA) and Brown-headed Cowbird (BHCO) was positively correlated with the biomass of Orthoptera while the relative abundance of American Pipit (AMPI), Eastern Kingbird (EAKI), Savannah Sparrow (SAVS), and Common Yellowthroat (COYE) was positively correlated with Diptera, Lepidoptera, Hemiptera and two other orders. The relative abundance of the aforementioned bird species was also highest in the drawdown zone in control, treatment, and drawdown zone sites (with the exception of Mosquito Creek reference sites). Some of these relationships were the same in 2010 and these bird and arthropod species and orders can be monitored at these reaches and treatments to assess ecological relationships and those relationships can be used to assess revegetation effectiveness over time.

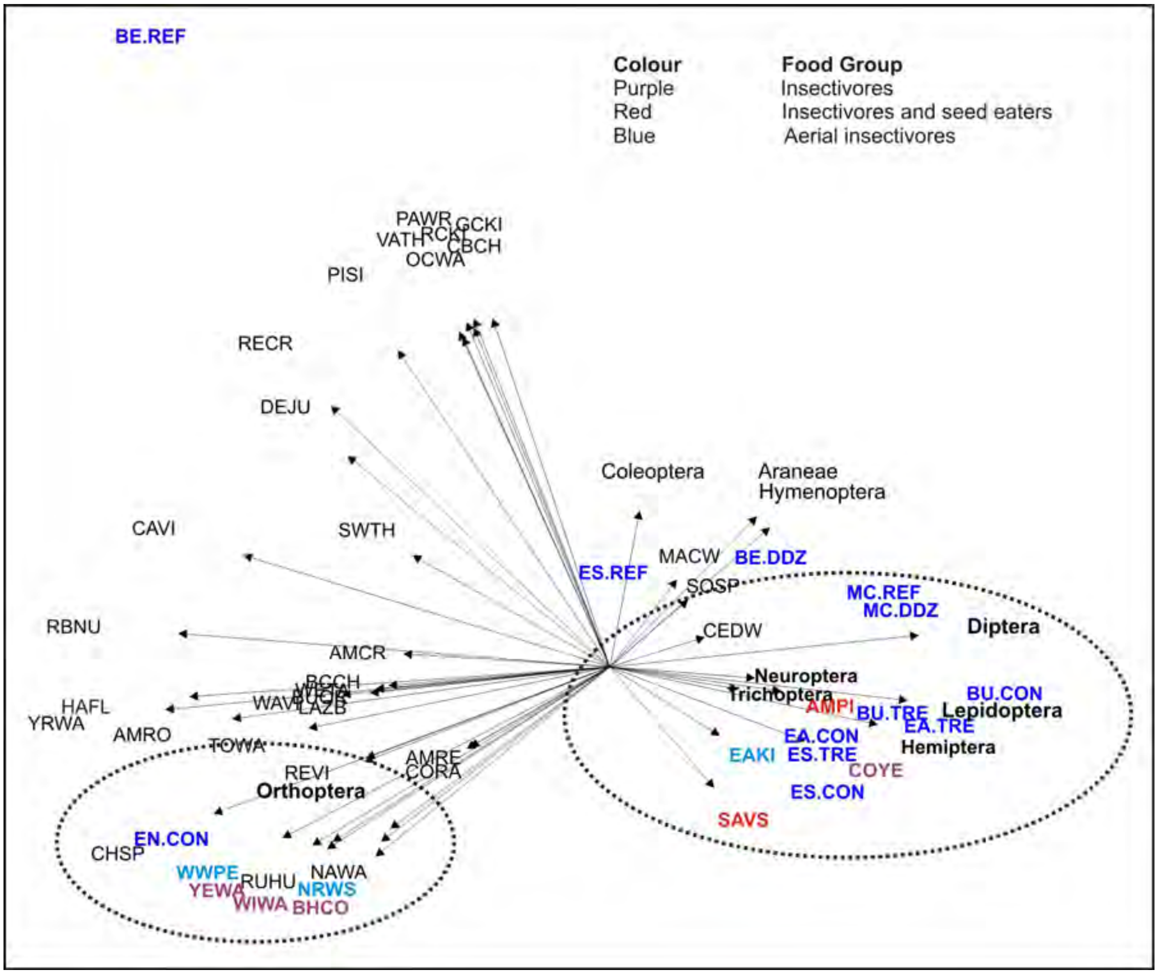


Figure 5-21: Principal Components Analysis ordination diagram with superposition of songbird species (colour-coded by food habit) and arthropod orders. Black vectors represent species. Axis 1 represents 28 per cent and axis 2 18 per cent of the variation in the multi-dimensional data set. Scaling is of type 2. BU.TRE = treatment sites, Burton Creek, BU.CON: control sites, Burton Creek of Burton, BU.REF: reference sites, Burton Creek; BE.DDZ: Drawdown sites, Beaton, BE.REF: reference sites, Beaton; EA.TRE: treatment sites, East Arrow Park, EA.CON: control sites, East Arrow Park; EN.TRE: treatment sites, Edgewood North; ES.TRE: treatment sites, Edgewood South, ES.CON: control sites, Edgewood South. Bird species codes are defined in Appendix 10-D

5.2.7 Mammals

5.2.7.1 Terrestrial mammals

Terrestrial mammal occurrences, including signs (e.g. tracks and scat) and visual observations, were documented at seven reaches sampled in 2011, and included records for 10 species and five taxonomic groups. The most commonly encountered signs were from deer (*Odocoileus* sp.), elk (*Cervus canadensis*), bear (*Ursus* sp.), and small mammals (Table 5-9). Terrestrial mammals that were documented least frequently included snowshoe hare (*Lepus americanus*), beaver (*Castor canadensis*), mustelids and coyote (*Canis latrans*). Five species documented in previous years were not recorded in 2011: yellow-pine chipmunk (*Neotamias amoenus*), yellow-bellied marmot (*Marmota flaviventris*), Columbian ground squirrel (*Spermophilus columbianus*), moose (*Alces americanus*) and American mink (*Neovison vison*). Grizzly bears (*Ursus arctos*) or their sign were observed only at Mosquito Creek with two records from the reference area and one from the drawdown zone. Grey wolf (*Canis lupus*), North American river otter (*Lontra canadensis*), canids and mustelids were also recorded only at Mosquito Creek in 2011, and all their occurrences were noted in the drawdown zone. A single record of coyote was documented in the drawdown zone of Edgewood South.

Table 5-9: Terrestrial mammals documented in each reach, year and treatment during spring and summer surveys in the Arrow Lakes Reservoir, 2009–2011 (control and treatments combined as drawdown zone [DDZ]). Total observations refer to the number of times a given species was documented. Total species indicates how many species were documented per year. Ref: reference site

Reach	Year	Treatment	American Mink	Bear sp.	Beaver	Black Bear	Canine sp.	Columbia Ground Squirrel	Coyote	Deer sp.	Elk	Grey Wolf	Grizzly Bear	Moose	Muskrat	Mustelid sp.	N.A. River Otter	Red Squirrel	Small Mammal sp.	Snowshoe Hare	White-tailed Deer	Yellow-bellied Marmot	Yellow-pine Chipmunk	Total Observations	Total Species
Beaton Arm	2009	DDZ			1		1				2						2							6	4
		REF				6					3							2						11	3
	2010	DDZ			3	1				4	4	2	1				1							16	7
		REF				2	1				5	1						1		1				11	6
	2011	DDZ		2	1	1					1						1							6	5
		REF		1							9							4						14	3
Burton	2009	DDZ					3		2	18	3			2										28	5
		REF			2	1	1		1	21	1			1					1		7			36	9
	2010	DDZ				2	1			24					1		2							30	5
		REF			1	2		1		4	1			1							5			15	7
	2011	DDZ								8	2									1				11	3
		REF								2	1								1					4	3
East Arrow	2009	DDZ					2			11	30			1										44	4
		REF																							
	2010	DDZ	1				1			4	5						1							12	5
		REF				2																		2	1
	2011	DDZ								4	2						1							7	3
		REF																							
Edgewood North	2009	DDZ				1	5			15	2													23	4
		REF																							
	2010	DDZ					1			5														6	2
		REF																				1	1	2	2
	2011	DDZ		2					1	8														11	3
		REF		1		2				1														4	3
Edgewood South	2009	DDZ					2			11	1													14	3
		REF																							
	2010	DDZ				2				25			4								1			32	4
		REF				7															4			11	2
	2011	DDZ																							
		REF		1																				1	1
Lower Inonoaklin	2009	DDZ																							
		REF																							
	2010	DDZ	1				2		1	2						1					1			8	6
		REF				3			1	1								2			2		1	10	6
	2011	DDZ								3														3	1
		REF																							
Mosquito Creek	2009	DDZ							1	4	3		1						1				1	11	6
		REF																							
	2010	DDZ		1		1			1	2	12	1	2			1	3							24	9
		REF		1		1				1	1		5							1				10	6
	2011	DDZ					2			3	7	3	1			1			2		2			21	8
		REF		5		3				4	2		2						10					26	6

The number of terrestrial mammal species or taxonomic groups observed in or adjacent to the drawdown zone of mid- and lower Arrow Lakes Reservoir in 2011 ranged from four species and four taxonomic groups in the drawdown zone of Mosquito Creek to no records from the reference sites of East Arrow Park and

Lower Inonoaklin and the drawdown zone of Edgewood South (Table 5-9). In 2011, 14 species were documented in the drawdown zone; seven were documented in the upland reference habitats at all reaches. For the first three years combined, 13 species and five taxonomic groups were documented in the drawdown zone; 13 species and four taxonomic groups were documented in the adjacent upland.

Species richness varied by reach, treatment and year. Species richness was highest in the upland reference sites of Burton Creek in 2009 and the drawdown zone of Mosquito Creek in 2010 (Figure 5-22). In 2011, the highest documented mammal species richness was in the drawdown zone of Mosquito Creek, which hosted eight species. The number of species observed in the drawdown zone ranged from one to nine, and the number observed in the upland reference sites ranged from zero to nine. Sampling effort in reference areas at some sites, such as Lower Inonoaklin and East Arrow was limited due to accessibility or steep terrain and this is reflected in the species richness totals for 2011. The treatments at Edgewood North in 2011 were either inundated or access was cut off by high reservoir levels during field surveys, which resulted in a lack of mammal sign observations.

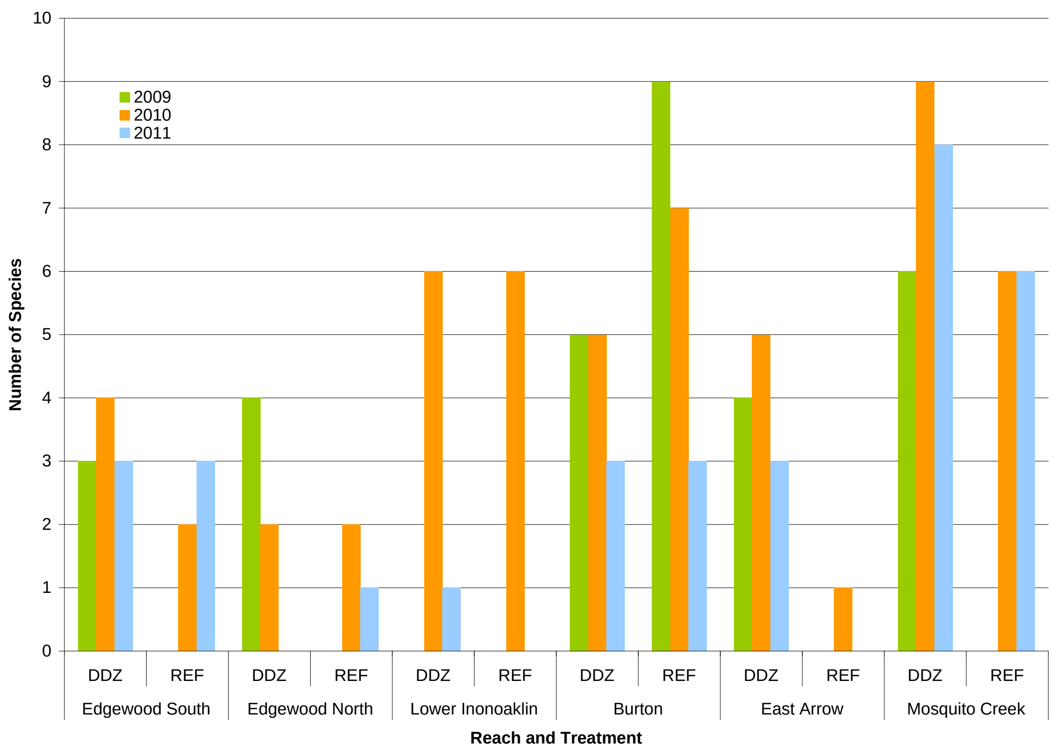


Figure 5-22: Number of terrestrial mammal species (species richness) documented per reach and treatment in the Arrow Lakes Reservoir 2009, 2010, and 2011. DDZ = drawdown zone sites; REF: reference sites

5.2.7.2 Bats

A total of 9,305 .wav files were analysed for bat presence. The total number of potential bat detections and potential species (species consensus) varied from site to site (Figure 5-23). Two sites–Edgewood North and Mosquito Creek–both had high numbers of potential detections and files that generated a species-level consensus. Mosquito Creek had a marginally higher number of potential detections, but the SonoBat 3.01 batch analysis resulted in a greater number of recorded files assigned to species by consensus for Edgewood North. Burton Creek was a distant third for the total number of possible detections, but less than 10 per cent of the recordings resulted in potential species matches. Both Beaton Arm and Lower Inonoaklin had more files with species-level consensus than did Burton Creek, despite having a much lower number of potential detections. Edgewood South had only 87 potential detections and 39 species-level consensuses, indicating that weather may have affected the bat detector's capacity to document high frequency calls.

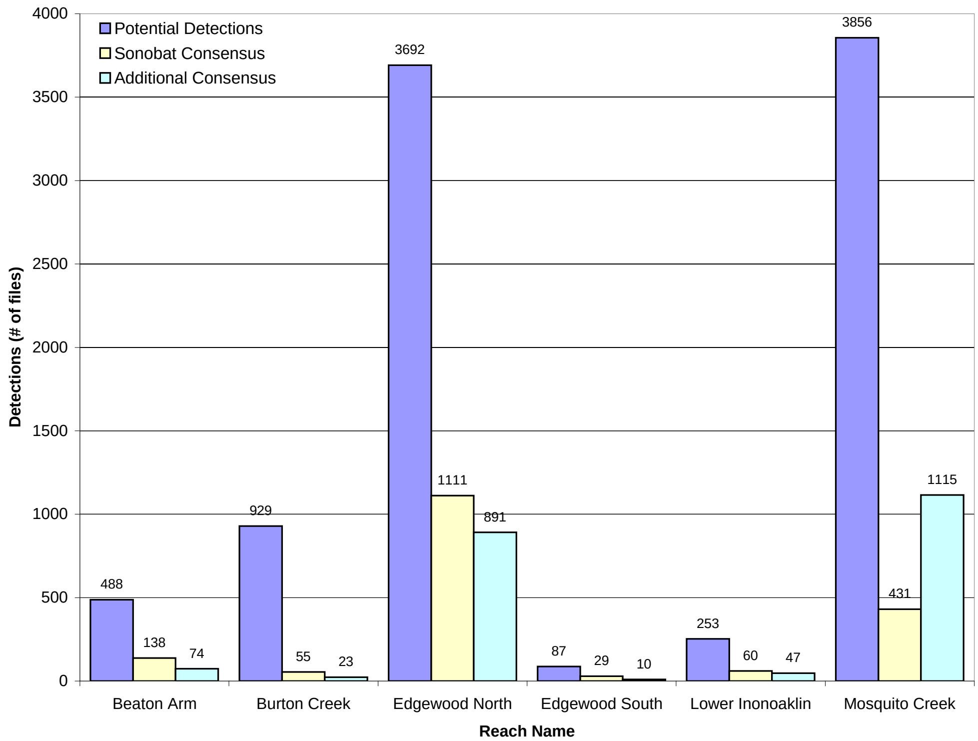


Figure 5-23: Potential bat detections and detections narrowed to species (i.e., species consensus by SonoBat software or additional selected detections) by site in the Arrow Lakes Reservoir, based on batch processing using SonoBat 3.01 WA west

Over the sampling period, nine bat species were recorded by the Song Meter SM2BAT 192kHz Stereo Ultrasonic Recorder units and were identified through SonoBat 3.01 WA west (Table 5-10). Five species—big brown bat (*Eptesicus fuscus*), silver-haired bat (*Lasionycteris noctivagans*), little brown myotis (*Myotis lucifugus*), western long-eared myotis (*M. evotis*) and Yuma myotis (*M. yumanensis*)—were documented in the drawdown zone at each reach sampled, while Townsend's big-eared bat (*Corynorhinus townsendii*) was potentially documented only once from the drawdown zone at Edgewood North.

Table 5-10: Bat species documented at each reach sampled in the Arrow Lakes Reservoir between August 20 and 26, 2011. An "X" indicates the species was recorded at the corresponding reach location. Townsend's big-eared bat (*Corynorhinus townsendii*) was the only species of potential significance due to its Blue List designation in B.C., but it has no designated status under COSEWIC

Common Name	Scientific Name	CDC[1] Status	COSEWIC[1] Status	Reach Code[2]					
				BE	BU	EN	ES	LI	MC
Townsend's big-eared bat	*Corynorhinus townsendii*	Blue	N/A			X			
Big brown bat	*Eptesicus fuscus*	Yellow	N/A	X	X	X	X	X	X
Silver-haired bat	*Lasionycteris noctivagans*	Yellow	N/A	X	X	X	X	X	X
Hoary bat	*Lasiurus cinereus*	Yellow	N/A			X		X	X
California myotis	*Myotis californicus*	Yellow	N/A			X			X
Western long-eared myotis	*Myotis evotis*	Yellow	N/A	X	X	X	X	X	X
Little brown myotis	*Myotis lucifugus*	Yellow	N/A	X	X	X	X	X	X
Long-legged myotis	*Myotis volans*	Yellow	N/A	X	X	X	X	X	
Yuma myotis	*Myotis yumanensis*	Yellow	N/A	X	X	X	X	X	X

[1] CDC = Conservation Data Centre; COSEWIC = Committee on the Status of Endangered Wildlife in Canada

[2] BE: Beaton Arm; BU: Burton Creek; EN: Edgewood North; ES: Edgewood South; LI: Lower Inonoaklin; MC: Mosquito Creek

Edgewood North had the highest species richness with nine species, but two of those were based on single potential species detections. The other reaches had similar richness, with six or seven species documented over the course of the sampling session (Figure 5-24). Weather may have been a factor at some sites as many recordings were compromised due to noise interference, especially those of larger bat species with lower frequency calls. Further sampling during periods with no precipitation and minimal wind may aid in determining the full range of species present at each site.

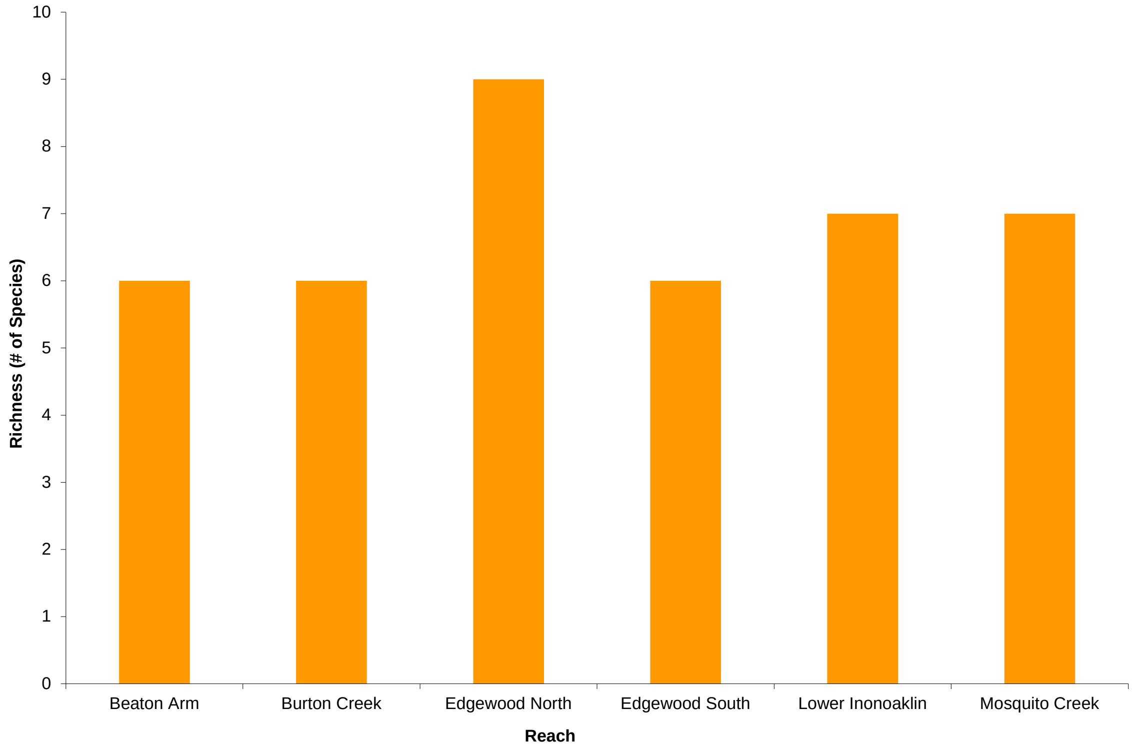
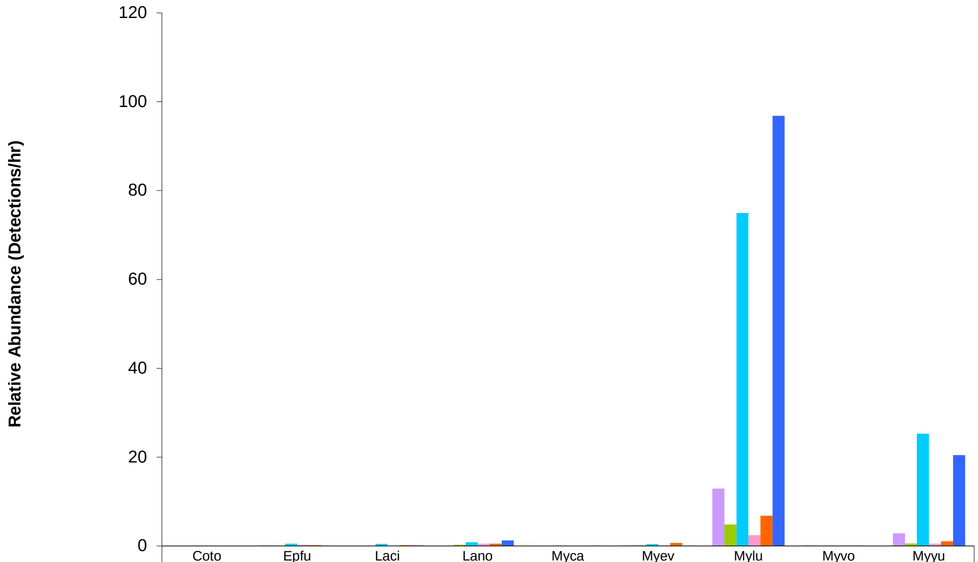


Figure 5-24: Species richness of bats documented from each reach sampled in arrow Lakes Reservoir, 2011

Little brown myotis bats were documented 3,052 times, making it the most commonly encountered species; it accounted for more than three-quarters of the files identified by consensus. Yuma myotis was the next most common (or most active) species in the study area, with 820 recognized recordings. Three other myotis species were recorded less frequently: western long-eared myotis was the least scarce of them with 22 recordings. Silver-haired bat was recorded 48 times, making it the most frequently documented larger bat species. The two other large bat species, big brown bat and hoary bat (*Lasiurus cinereus*), were found in low densities, with only 19 and 13 files, respectively. Townsend's big-eared bat had one potential record over the entire survey period.

The relative abundance (total consensus detections) of bat species by reach did not reveal any obvious trends other than little brown bat (Mylu) was the most common bat species at all of the reaches sampled (Figure 5-25). Yuma myotis (Myyu) was the next most common species at all sites, aside from Edgewood South where it had an equal number of occurrences as silver-haired bat (Lano). The most common large bat species at all sites, except Beaton Arm, was silver-haired bat (Laci).



	Coto	Epfu	Laci	Lano	Myca	Myev	Mylu	Myvo	Myyu
Beaton Arm		0.15		0.08		0.15	12.92	0.15	2.85
Burton Creek		0.08		0.31		0.15	4.85	0.08	0.54
Edgewood North	0.05	0.51	0.46	0.82	0.05	0.41	74.97	0.10	25.28
Edgewood South		0.31		0.51		0.10	2.46	0.10	0.51
Lower Inonoaklin		0.18	0.18	0.54		0.72	6.82	0.09	1.08
Mosquito Creek		0.08	0.15	1.23	0.08	0.08	96.85		20.46

Bat Species Code

Figure 5-25: Relative abundance of bat species documented in the drawdown zone of mid- and lower Arrow Lakes Reservoir, summer 2011. Coto: *Corynorhinus townsendii*; Epfu: *Eptesicus fuscus*; Laci: *Lasionycteris noctivagans*; Lano: *Lasiurus cinereus*; Myca: *Myotis californicus*; Myev: *Myotis evotis*; Mylu: *Myotis lucifugus*; Myvo: *Myotis volans*; Myyu: *Myotis yumanensis*

To increase future sampling effectiveness, we investigated detections per hour for three distinct time periods over which the bat detectors were recording activity (Figure 5-26). Sampling effort varied between time periods, so the relative abundance values were standardized to the number per period hour. A fairly consistent trend in the transformed data was evident (Figure 5-26). For most species, the highest number of detections was recorded during the night period, followed by evening twilight. The least amount of bat activity was recorded during morning twilight, which was likely the result of bat activity ceasing most mornings at around 5:15 a.m. Considering the rather abrupt end to activity in the morning, future sampling may be conducted for the same length but ending half an hour before sunrise.

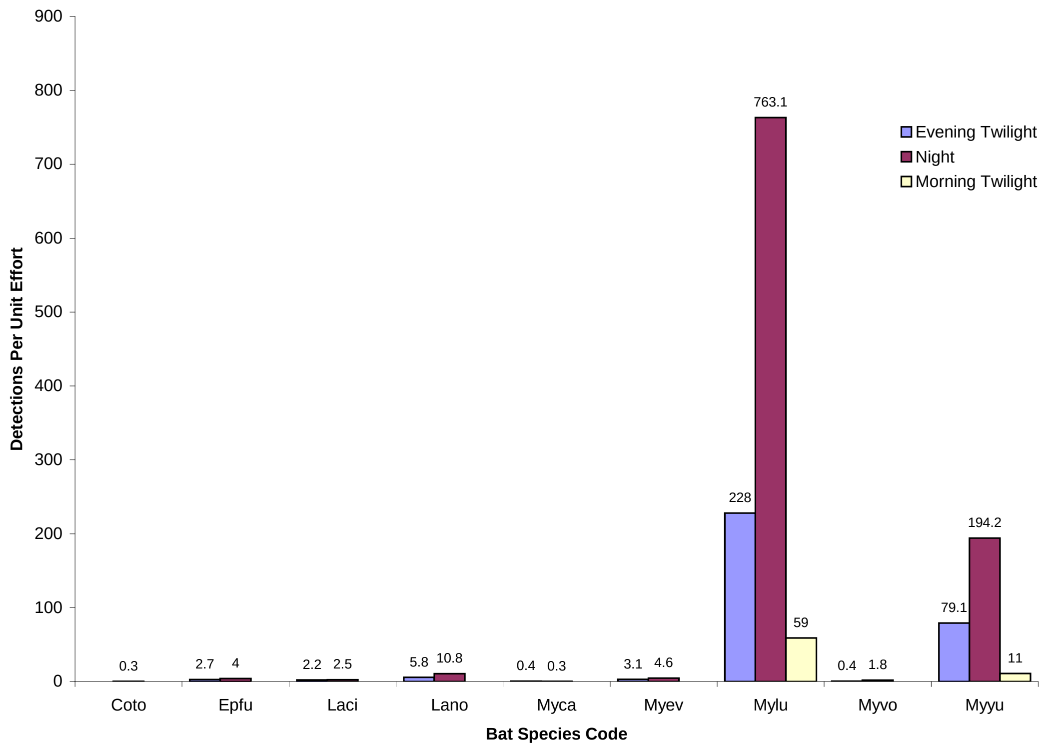


Figure 5-26: Relative abundance of bat species documented during specific time periods of activity in mid- and lower Arrow Lakes Reservoir, summer 2011. Coto: *Corynorhinus townsendii*; Epfu: *Eptesicus fuscus*; Laci: *Lasionycteris noctivagans*; Lano: *Lasiurus cinereus*; Myca: *Myotis californicus*; Myev: *Myotis evotis*; Mylu: *Myotis lucifugus*; Myvo: *Myotis volans*; Myyu: *Myotis yumanensis*

5.2.7.3 Winter Mammal Surveys

An aerial survey of the Arrow Lakes reservoir was conducted over two days on February 6 and February 7, 2012 and covered 592.73 linear kilometres and included 4 hours and 42 minutes of total survey time (Table 5-11; Appendix 10-E).

Table 5-11: Summary of survey time and distance for each winter aerial survey of the drawdown zone of the Arrow Lakes Reservoir, 2012. MU: management unit (see Figure 4-2)

	February 6, 2012		February 7, 2012		Total	
MU	**Time**	**km**	**Time**	**km**	**Time**	**km**
4-8						
4-9	0:11:36	30.18			0:11:36	30.18
4-14	0:23:21	58.14			0:23:21	58.14
4-15			1:13:58	152.49	1:13:58	152.49
4-31			0:39:03	85.08	0:39:03	85.08
4-32	1:21:07	167.26			1:21:07	167.26
4-33			0:52:47	97.62	0:52:47	97.62
4-38						
4-39	0:00:45	1.96			0:00:45	1.96
Totals	**1:56:49**	**257.54**	**2:45:48**	**335.19**	**4:42:37**	**592.73**

One to five species were documented in both the drawdown zone and upland habitats of each management unit (Figure 5-27). Management Unit 4-14 had the lowest richness with two species observed in the upland area and one species in the drawdown zone, while Management Units 4-31 and 4-32 had the highest diversity with five species in the upland and drawdown zone, respectively. Overall, more unique species were detected in the upland area (n = 9) than in the drawdown zone (n = 6).

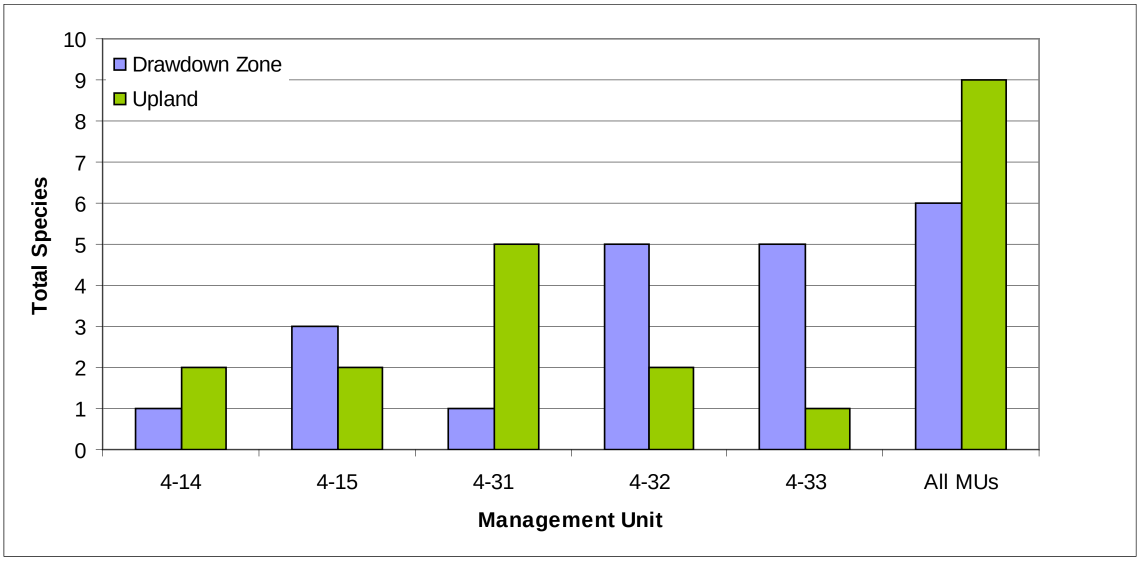


Figure 5-27: Total number of species observed in the drawdown zone and upland habitats of the Arrow Lakes Reservoir by management unit (MU). See Figure 4-2 for distribution of management units

During the winter mammal surveys, 82 observations of mammals or their sign were made in and adjacent to the drawdown zone (111 total observations were made in all habitats). Visual observations comprised 23 per cent of all observations; tracks or other sign (e.g. bones) comprised 77 per cent of all observations. The number of observations attributed to the drawdown zone (*n* = 82) was far greater than that attributed to upland habitats (*n* = 29). Of the 82 observations made in the drawdown zone, most (*n*: 76) were tracks. Similarly, only 20 visual observations out of 29 total observations (*n* = 9 nine observations of tracks) were recorded in upland habitats. The distribution of mammal sign (visual or tracks) by management unit is shown in Table 5-12.

Table 5-12: Distribution of mammal observations by management unit (MU), species, observation type and habitat. DDZ: drawdown zone; UPL: upland. The distribution of management units is shown in Figure 4-2

	4-9				4-14				4-15				4-31				4-32				4-33						All MU's					
	Visual		Tracks		Visual		Tracks		Visual		Tracks		Visual		Tracks		Visual		Tracks		Sign		Tracks		Visual		Sign		Visual		Tracks	
Species Name	**DDZ**	**UPL**	**DDZ**	**UPL**	**DDZ**	**UPL**	**DDZ**	**UPL**	**DDZ**	**UPL**	**DDZ**	**UPL**	**DDZ**	**UPL**	**DDZ**	**UPL**	**DDZ**	**UPL**	**DDZ**	**UPL**	**DDZ**	**UPL**	**DDZ**	**UPL**	**DDZ**	**UPL**	**DDZ**	**UPL**	**DDZ**	**UPL**	**DDZ**	**UPL**
Alces americanus																		6	1				1							6	2	
Canis latrans																			1				1		1				1		2	
Canis lupus																		2					1							2	1	
Cervus canadensis											2								2	2			5			3				3	9	2
Odocoileus hemionus														5																5		
Odocoileus sp.				1			5				22				15	1	4		8	2	1		10				1		4		60	4
Odocoileus virginianus																										2				2		
Oreamnos americanus										1																				1		
Ovis canadensis										1																				1		
Ungulate											1								1	3											2	3
Total Observations				**1**			**5**			**2**	**25**			**5**	**15**	**1**	**4**	**8**	**13**	**7**	**1**		**18**		**1**	**5**	**1**		**5**	**20**	**76**	**9**
Total Species				**1**			**1**			**2**	**3**			**1**	**1**	**1**	**1**	**2**	**5**	**3**	**1**		**5**		**1**	**2**	**1**		**2**	**7**	**6**	**3**

The density of mammals (number per linear kilometre, all species combined) was highest in MU 4-33, followed by MU 4-31 (Figure 5-28). MU 4-9 had the lowest density of all management units surveyed. Wildlife use of the drawdown zone was highest in MUs 4-33, 4-31 and 4-15. MUs 4-14 and 4-15 are situated in lower Arrow Lakes Reservoir; MU 4-32 is situated in the north (Figure 4-2). Both MUs 4-15 and 4-32 contain west-and/or south-facing warm aspect slopes, which provide high quality ungulate winter range habitat. The dearth of observations in MU 4-9 is consistent with the presence of northerly aspects and dense coniferous forests, which dominate this management unit.

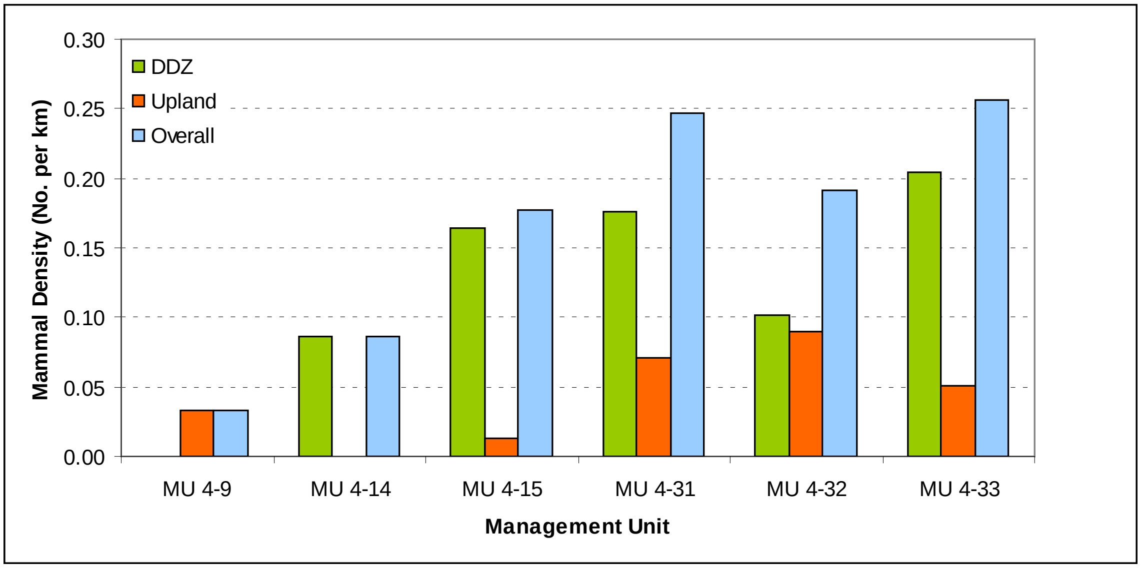


Figure 5-28: Density of mammals (all species combined) by habitat type and management unit

The density of ungulates (moose, elk, mule deer and white-tailed deer) varied by management unit (Figure 5-29). Moose and their sign were observed in only two management units. The highest density of moose was in MU 4-32, which is situated along the west side of the reservoir (Figure 4-2) and contains the highest number of cut blocks and regenerating forest. Elk typically occurred in low densities and were documented in three of the six management units. Mule deer and white-tailed deer were each observed in only one of the six management units, and densities of mule deer were higher than those of white-tailed deer. At least one species of deer was observed in all management units, with the highest densities in MUs 4-31 and 4-15, which is consistent with the location of high suitability ungulate winter range.

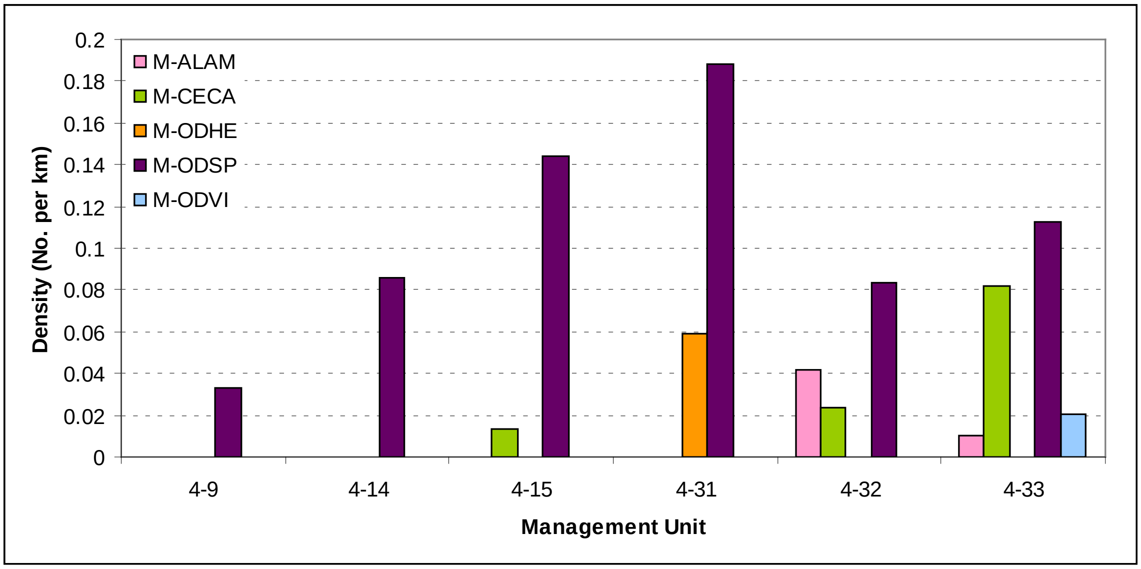


Figure 5-29: Ungulate density (visual and track observations combined) in the management units adjacent to Arrow Lakes Reservoir. M-ALAM: moose (*Alces americanus*); M-CECA: elk (*Cervus Canadensis*); M-ODHE: mule deer (*Odocoileus hemionus*); M-ODVI: white-tailed deer (*O. virginianus*); M-ODSP: deer species

Species-specific densities by habitat type (drawdown zone or upland) are shown in Table 5-13. In general, densities were low for all species, but consistent with 2010, moose densities were always higher in upland habitats, and elk densities were higher in the drawdown zone. Unlike 2010, both species of deer were generally more abundant in the drawdown zone than in upland habitats, except in MU 4-9, where deer were recorded in only upland habitats. Overall, more animals were observed in upland habitats, but more tracks were recorded in the drawdown zone. This may be a function of snowpack at the time of the survey, which was relatively low. This made it easier to see tracks in the drawdown zone, which is not heavily vegetated relative to upland habitats.

Table 5-13: Distribution of mammal densities by management unit (MU), species, observation type and habitat. DDZ= drawdown zone, UPL: upland. The distribution of management units is shown in Figure 4-2

	4-9				4-14				4-15				4-31				4-32				4-33						All MU's					
	Visual		Tracks		Visual		Tracks		Visual		Tracks		Visual		Tracks		Visual		Tracks		Sign		Tracks		Visual		Sign		Visual		Tracks	
Species Name	DDZ	UPL	DDZ	UPL	DDZ	UPL	DDZ	UPL	DDZ	UPL	DDZ	UPL	DDZ	UPL	DDZ	UPL	DDZ	UPL	DDZ	UPL	DDZ	UPL	DDZ	UPL	DDZ	UPL	DDZ	UPL	DDZ	UPL	DDZ	UPL
Alces americanus																		0.04	0.01				0.01							0.01	0.00	
Canis latrans																			0.01				0.01		0.01				0.00		0.00	
Canis lupus																		0.01					0.01							0.00	0.00	
Cervus canadensis											0.01								0.01	0.01			0.05			0.03				0.01	0.02	0.00
Odocoileus hemionus														0.06																0.01		
Odocoileus sp.				0.03			0.09				0.14				0.18	0.01	0.02		0.05	0.01	0.01		0.10				0.00		0.01		0.10	0.01
Odocoileus virginianus																										0.02				0.00		
Oreamnos americanus										0.01																				0.00		
Ovis canadensis										0.01																				0.00		
Ungulate											0.01								0.01	0.02											0.00	0.01
Total Density				0.03			0.09			0.01	0.16			0.06	0.18	0.01	0.02	0.05	0.08	0.04	0.01		0.18		0.01	0.05			0.01	0.03	0.13	0.02

5.2.8 Amphibians and Reptiles

Formal surveys for amphibians and reptiles were not conducted in 2011. However, we continued to make incidental observations at all reaches sampled in mid- and lower Arrow Lakes Reservoir. Amphibian and reptile data will be collected again in 2012 using a standardized approach (as per CLBMON-37). Notable observations included the presence of breeding Western Toads (*Anaxyrus boreas*) at Burton Creek (and the observation of tadpoles and toadlets throughout the year) and observations of numerous garter snakes (both *Thamnophis elegans* and *T. sirtalis*) at Edgewood South. Searches for both Rubber Boa (*Charina bottae*) and Western Skink (*Plestiodon skiltonianus*) were conducted at Edgewood North in 2011, but only Western Skinks were observed. Amphibian and reptile observations are not generally correlated with revegetated areas, but with specific habitat features such as wetlands, rocky outcrops, and woody debris. Hawkes and Howard (2012) discuss some of these habitat elements (wetlands and woody debris) as components of physical works implemented to improve wildlife habitat in the drawdown zone of mid- and lower Arrow Lakes Reservoir.

5.3 Wildlife Habitat Enhancement

Three wildlife physical works projects are proposed for mid- and lower Arrow Lakes, all of which involve the creation, preservation, or enhancement of shallow-wetland habitat. The total area of shallow wetland habitat created would be approximately 4.1 ha (2.8 ha at Burton Creek and 1.3 ha at Edgewood South) and an additional 6.2 ha at Lower Inonoaklin Road would be enhanced.

In addition to the three physical works proposed for the drawdown zone of mid and lower Arrow Lakes Reservoir, the Fish and Wildlife Compensation Program – Columbia Region has proposed to undertake a Western Skink and Rubber Boa enhancement project at Edgewood North. This project would affect upland habitat immediately adjacent to the drawdown zone.

Overall, the ability to improve wildlife habitat in the drawdown zone of mid and lower Arrow Lakes Reservoir is limited by topography. Much of the drawdown zone is steep and/or rocky and does not provide the opportunity to implement physical works. Areas that are relatively flat have been identified for physical works. There are additional areas, such as the mouths of small creeks that flow into the reservoir that could be manipulated to increase the amount of shallow wetland habitat in or adjacent to the drawdown zone of Arrow Lakes. However, these projects require further consideration and are not recommended at this time.

6.0 DISCUSSION

CLBMON-11B1, initiated in 2009, is a long-term wildlife monitoring project that aims to assess the efficacy of revegetation prescriptions in enhancing the suitability of habitats in the drawdown zone for wildlife, and to develop a minimum of three wildlife enhancement prescriptions that can be implemented in the drawdown zone to further improve habitat suitability. The focal species groups selected for this study are songbirds, arthropods and mammals (ungulates). In addition to studying these groups, bats were incorporated into the 2010 sampling program because of the known relationships between bats, wetland and riparian habitat, and arthropods, which are their primary food source. In 2011 we sampled the same suite of wildlife as in 2010.

The revegetation prescriptions applied in the drawdown zone are likely to affect prey populations (terrestrial and aerial arthropods) before they affect the predators of those arthropods (songbirds and bats). The direction and magnitude of those changes in arthropod populations will be tracked over time and will serve as a metric to assess the efficacy of each revegetation prescription applied in the drawdown zone. Specific revegetation prescriptions (live stakes) may increase the volume of ungulate browse in the drawdown zone, which is why ungulates are included in the long-term monitoring program.

In general there does not appear to be a strong relationship between the biomass of arthropods or the relative abundance of songbirds and revegetation prescriptions applied in the drawdown zone. There are distinct groupings of both arthropods and songbirds that partition themselves along an environmental gradient representing the drawdown zone and adjacent upland habitats; these groupings were consistent between 2010 and 2011 (see Hawkes et al. 2011a). The inherent natural variation associated with communities of songbirds and arthropods and the relatively short time since the revegetation prescriptions were applied are likely contributing to the lack of observed patterns. More time is required to assess how species richness, biomass, and relative abundance change as a result of the implementation of the revegetation prescriptions.

Songbirds and arthropods are likely suitable indicators to assess changes in habitat quality induced by the revegetation prescriptions. This is based on the persistence of distinct drawdown zone and upland songbird and arthropod communities (Figure 5-10, Figure 5-20) and on the relationships between songbirds and their arthropod prey (Figure 5-21). Although density independent events appear to be affecting the biomass of arthropods (e.g., wind or rain events may have affected the total catch of arthropods in 2011), a temporal data set consisting of multiple years should indicate how arthropod biomass is changing and whether that change can be correlated to treatments.

Ungulates use the drawdown zone, but the use does not appear to be related to the revegetated areas (Appendix 10-E). However, these observations are based on one or two aerial surveys per year in 2010 and 2011, which may not be representative of the actual use of the drawdown zone by ungulates. To resolve this, pellet plots were installed in 2011 (Appendix 10-B). These plots should be counted and cleared in 2012 and should provide a better indication of the use of the drawdown zone by ungulates, and more specifically, whether revegetated areas are used differently than control sites.

Monitoring the use of the drawdown zone by bats has resulted in the documentation of 10 bat species in various locations in mid- and lower Arrow Lakes Reservoir. The relationship between bats and revegetation prescriptions has been difficult to assess, mainly because the light traps we use are sampling a relatively small area and the efficacy of those traps is affected by light wind and rain. We will continue to monitor the distribution of bats in the drawdown zone while refining our night-flying insect trapping methods.

The effectiveness monitoring program developed and implemented in mid- and lower-Arrow Lakes Reservoir will likely need to be refined to ensure that the methods used to monitor the revegetation physical works can also be used to monitor the efficacy of proposed wildlife physical works promoted in Hawkes and Howard (2011). Recommendations regarding these refinements are provided in Section 7.0.

6.1 Management Questions and Hypotheses

Wildlife use of the drawdown zone relative to the 14 hypotheses listed in Section 2.0 is best discussed with respect to the management questions for this project and in the context of the broad themes associated with the management questions. For CLBMON-11B, several hypotheses strive to address how the revegetation of the drawdown zone affects wildlife use of the zone, as measured by indices of use or biomass. Other hypotheses address wildlife habitat specifically. Concurrent with the assessment of wildlife habitat suitability and use, certain hypotheses seek to determine whether various revegetation techniques affect habitat quality or use by wildlife in the drawdown zone. The hypotheses associated with CLBWORKS-29B address how wildlife physical works affect habitat quality as well as the distribution and use of the drawdown zone by wildlife, while at the same time assessing the efficacy of different physical works.

Table 6-1 summarizes the current status of CLBMON-11B1 in terms of our ability to test hypotheses and address management questions. Our progress towards answering each management questions is discussed in more detail below.

Table 6-1: Summary of the relationship between the broad themes, three management questions (MQ) and 14 hypotheses associated with CLMBON-11B1. The hypotheses addressed by each MQ are in bold. Whether the MQ will be addressed is indicated, as is the type of data required to address the MQ. The current status of the project (with respect to data collection, etc.) is identified, and an indication of when preliminary results related to addressing each MQ and hypothesis is provided. Text under the hypotheses indicates the approach and/or data that will be used to address the MQ and hypotheses

Theme and Question	Component	Hypotheses and General Approach	Will MQ be Answered?	Data Required	Current Status	Preliminary Results Expected
Revegetation, wildlife, and wildlife habitat	**CLBMON-11B**	**HA_{1} HA_{1A} HA_{1B} HA_{1C} HA_{1D} HA_{1E}** HA_{2} HA_{2A} HA_{2B} HA_{2C} HA_{2D} HA_{3} HA_{3A} HA_{3B}				
MQ: Are the revegetation and the wildlife physical works projects effective at enhancing wildlife habitat in the drawdown zone?		Only revegetation prescriptions applied to date. Focal species groups (songbirds, arthropods and ungulates); biophysical habitat mapping; habitat suitability/capability	Yes	Time Series	2nd full year of data collected (baseline + two consecutive monitoring years)	Too early to assess trends. Likely can in Year 5 (2013)
MQ: If revegetation and the wildlife physical works projects enhance wildlife habitat in the drawdown zone, to what extent does the revegetation program and the wildlife physical works projects increase the productivity of habitat in the drawdown zone for wildlife?		Only revegetation prescriptions applied to date. Focal species groups (songbirds, arthropods and ungulates); trophic linkages; assessment of changes in relative abundance, diversity and richness over time relative to each group, the interactions of those groups and to the revegetation prescriptions and/or wildlife enhancement prescriptions	Yes	Time Series	See above	Too early to assess trends. Likely can in Year 5 (2013)
Revegetation and changes to productivity	**CLBMON-11B**	HA_{1} HA_{1A} HA_{1B} HA_{1C} HA_{1D} HA_{1E} HA_{2} HA_{2A} HA_{2B} HA_{2C} HA_{2D} HA_{3} **HA_{3A}** HA_{3B}				
MQ: Are the revegetation and the wildlife physical works projects effective at enhancing wildlife habitat in the drawdown zone?		Only revegetation prescriptions applied to date. Focal species groups (songbirds, arthropods and ungulates); biophysical habitat mapping; habitat suitability/capability	Yes	Time Series	See above	Too early to assess trends. Likely can in Year 5 (2013)
Revegetation: a comparison of techniques	**CLBMON-11B**	HA_{1} HA_{1A} HA_{1B} HA_{1C} HA_{1D} HA_{1E} HA_{2} HA_{2A} HA_{2B} HA_{2C} HA_{2D} **HA_{3}** HA_{3A} HA_{3B}				
MQ: Are some methods or techniques more effective than others at enhancing wildlife habitat in the drawdown zone?		Only revegetation prescriptions applied to date and prescriptions not applied in a way that can be used to assess treatment effects across the reservoir - site-specific responses only. Generate comparisons of relative abundance, diversity and richness data obtained for each group relative to each revegetation prescription. Likely a reach-specific analysis because of lack of replication of prescriptions.	Yes	Time Series	See above	Too early to assess trends. Likely can in Year 5 (2013)
MQ: If revegetation and the wildlife physical works projects enhance wildlife habitat in the drawdown zone, to what extent does the revegetation program and the wildlife physical works projects increase the productivity of habitat in the drawdown zone for wildlife?		Only revegetation prescriptions applied to date. Focal species groups (songbirds, arthropods, ungulates); trophic linkages; assessment of changes in relative abundance, diversity, and richness over time relative to each group, the interactions of those groups, and to the revegetation prescriptions and/or wildlife enhancement prescriptions.	Yes	Time Series	See above	Too early to assess trends. Likely can in Year 5 (2013)
Physical works	**CLBMON-29B**	HA_{1} HA_{1A} HA_{1B} HA_{1C} HA_{1D} HA_{1E} **HA_{2} HA_{2A} HA_{2B} HA_{2C} HA_{2D}** HA_{3} HA_{3A} **HA_{3B}**				
MQ: Are the revegetation and the wildlife physical works projects effective at enhancing wildlife habitat in the drawdown zone?		Not yet implemented. Focal species groups (songbirds, arthropods, ungulates); biophysical habitat mapping; habitat suitability/capability	Yes (if physical works get implemented). Will require revisions to monitoring program	Time Series	See above	Contingent on physical works implementation schedule
MQ: If revegetation and the wildlife physical works projects enhance wildlife habitat in the drawdown zone, to what extent does the revegetation program and the wildlife physical works projects increase the productivity of habitat in the drawdown zone for wildlife?		Not yet implemented. Focal species groups (songbirds, arthropods and ungulates); trophic linkages; assessment of changes in relative abundance, diversity, and richness over time relative to each group, the interactions of those groups and to the revegetation prescriptions and/or wildlife enhancement prescriptions	Yes (if physical works get implemented). Will require revisions to monitoring program	Time Series	See above	Contingent on physical works implementation schedule

6.1.1 CLBMON-11B – Revegetation, Wildlife and Wildlife Habitat

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

Sampling for focal species groups and incorporating incidental data and data from other monitoring programs into this project will indicate if the application of revegetation prescriptions changes wildlife use of the drawdown zone over time. Although the program design suffers from a lack of replication (the application of treatment varies by reach and elevation), we can use the data collected to assess site and species-specific responses to the revegetation prescriptions. Assessing the overall patterns of response relative to revegetation (irrespective of prescription) will indicate if revegetation changes wildlife use of the drawdown zone. Because of the differential application of treatments across reaches an assessment of change relative to revegetation will not be made by prescription for the entire reservoir, but by each reach sampled.

Trends in habitat use and species presence will likely become more evident with additional years of data collection. The development of the biophysical habitat map in 2010 can also be used as a tool to map the distribution of high, moderate and low suitability habitat for select species (i.e., those that occur on the conservation framework list for the Columbia Region). Those polygons assessed as high, moderate and low habitat suitability can be field-truthed to refine the map and to better determine the distribution of certain wildlife species in and adjacent to the drawdown zone.

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

The biophysical habitat map developed in 2010 will be used (in 2013) to ground-truth the distribution and occurrence of high, moderate and low suitability wildlife habitat in and adjacent to the drawdown zone of mid- and lower Arrow Lakes Reservoir. Using a variety of data sources, including data collected for CLBMON-37, CLBMON-12, CLBMON-33 and CLBWORKS-2, and historical fur harvest data, historical ungulate data, data collected by the Columbia Basin Fish and Wildlife Compensation Program, and data from this study, we will assess the relative species richness of each habitat type. The baseline developed for the drawdown zone will be based on the number of species, particularly focal species, present in the drawdown zone in each of the control and treatment sites. This will provide the means to assess whether revegetating the drawdown zone changes the spatial extent and/or suitability of wildlife habitat in the drawdown zone.

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

The presence of two main groups of songbirds into an upland and drawdown zone assemblage aligns with the findings of Hawkes et al. (2010, 2011a). There does not appear to be a single species or a group of species driving the formation of the drawdown zone group. However, two species (Northern Rough-winged Swallow [*Stelgidopteryx serripennis*] and Violet-green Swallow [*Tachycineta thalassina*]) were associated with the drawdown zone in 2009 and 2010, and Northern Rough-winged Swallow was documented again in 2011. Both of these species tend to forage over open areas. The presence of at least one of these species (Northern Rough-winged Swallow) in the drawdown zone group of birds lends support to our assumption that this species might be a suitable indicator of change associated with the revegetation of the drawdown zone. The species or a subset of the species that form the upland group may indicate if the revegetation prescriptions, particularly the establishment of live stakes, effectively increase the amount of forested habitat in the drawdown zone. Mattson and Marshall (2009) selected indicator species based on an analysis of detection rates. In 2013 we should have enough data to use an analysis that follows Mattson and Marshall (2009) or Etterson et al. (2009) to refine the selection of indicator species.

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

Low-elevation southeast to southwest aspects adjacent to the Upper Arrow Lakes Reservoir provide important mid- and late winter and early spring habitat for elk, mule deer and white-tailed deer (Clarke 1997, 1999). Poole et al. (2001) reported that the Halfway River area in mid-Arrow Lakes Reservoir and lower Arrow Lakes Reservoir (east side near Deer Park) provide high-value deer winter range habitat. Our survey data support the findings of these studies. We also found that high-quality moose winter range occurs on the west side of the reservoir across from Nakusp.

Although we observed more ungulate tracks in the drawdown zone during our single aerial survey in February 2012, we are not convinced that ungulates are using the drawdown zone more than adjacent upland habitats. In 2010 we documented more ungulates in upland habitats (Hawkes et al. 2011a) and the drawdown observations did not tend to be correlated with revegetated areas (based on a visual comparison of ungulate observations relative to each reach sampled). Revegetation in portions of the drawdown zone may improve habitat suitability over time; however, too little time has passed to assess the efficacy of each revegetation prescription in improving ungulate habitat suitability. Further, given the extent of high-value spring and winter range that is immediately adjacent to the drawdown zone (Clarke 1997, 1999), it is difficult to determine how the revegetation of ~71 ha (Table 5-3) of the drawdown zone will measurably improve habitat suitability for ungulates. The installation of pellet plots in 2011 should help resolve questions regarding the use of revegetated areas by ungulates and whether that use is different from use of control sites.

If ungulate use of the drawdown zone is considered to be a critical measure of the success of this project, then measures to enhance wildlife habitat in upland areas adjacent to the drawdown zone may be of greater benefit to overall ungulate populations than would enhancement of drawdown zone habitats. Options for enhancing upland ungulate habitat include prescribed burning and brushing/slashing prescriptions, both of which remove overgrown and decadent vegetation from the understorey and allow for an increase in fresh growth, which acts as both cover and a food source. These types of prescriptions were investigated as potential wildlife enhancement projects, and they continue to be considered for development of a wildlife enhancement strategy for mid- and lower Arrow Lakes Reservoir. However, they have not been promoted as priority enhancement projects by Hawkes and Howard (2011) and are retained for future consideration.

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

Amphibian and reptile data are collected to support both CLBMON-37 and CLBMON-11B1. The use of the drawdown zone by amphibians and reptiles is reported in Hawkes and Tuttle (2009, 2010) and Hawkes et al. (2011b). CLBMON-37 will be implemented again in 2012. As indicated in Hawkes et al. 2011b) the revegetation prescriptions applied in the drawdown zone are unlikely to improve habitat suitability for amphibians and reptiles. It is more likely that habitat elements such as woody debris, rocky outcrops, and wetland habitat will benefit amphibians and reptiles. The wildlife prescriptions promoted by Hawkes and Howard (2011) will increase the amount of shallow wetland habitat in the drawdown zone. Other habitat elements (e.g., woody debris and rock piles) could be incorporated into those prescriptions to improve habitat heterogeneity and suitability for amphibians and reptiles.

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

The biomass of arthropods has varied substantially since 2009 and is likely related to the effect of environmental conditions on trapping success. It is apparent that certain orders and/or families of arthropods are associated with either drawdown zone or upland reference sites; however, not enough time has passed to assess whether arthropod orders and/or families are associated with a given revegetation prescriptions. We also do not know if the application of revegetation prescriptions will change the biomass or species richness of arthropods in the near term or if a longer (i.e., 10-year) data set is required to asses this. This hypothesis will most likely be tested after Year 5 of this study and will be based on an assessment of three years of monitoring data (excluding the data collected in 2009 during the development of the monitoring program).

6.1.2 CLBMON-11B Revegetation and Changes to Productivity

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

This hypothesis is related to HA_{1A} and HA_{1E}. Habitat suitability ratings can be derived using the biophysical habitat mapping developed in 2010. Using this map, the distribution of high, moderate and low suitability wildlife habitat (as it relates to each of the focal species groups) will be identified in 2013 and changes to the distribution or spatial extent of those habitats will be monitored over time. Site productivity (arthropod biomass) will continue to be monitored over time using the methods described in this report to determine how biomass changes relative to revegetation prescription, reservoir elevation and other potentially confounding variables. Forage production in the drawdown zone will be assessed as part of the habitat suitability mapping exercise and by identifying areas of the drawdown zone where browse species (such as willow) occur, which can likely be extracted from the biophysical habitat map and from data obtained during habitat surveys and winter aerial surveys. Winter mammal surveys should be considered for at least one more year (2013) to determine the extent to which mammals (especially ungulates) use the drawdown zone during winter.

6.1.3 CLBMON-11B Revegetation: Comparisons of Techniques

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

The suitability of wildlife habitat in the drawdown zone will be assessed through biophysical habitat mapping (see above), through data collection associated with focal species groups, and through the inclusion of incidental data and data obtained by other researchers working in the area. These data will be collated to develop an index of biodiversity based on all taxa for each reach and each revegetation treatment. The relationship between the biodiversity index and revegetation prescription applied to the drawdown zone will be made on a reach-by-reach basis because treatment varies by reach (most treatments were not applied in all reaches). However, we can assess the efficacy of each treatment per reach by tracking biodiversity within each revegetation prescription over time. This assessment will be made in 2013 after the third year of data collection.

6.1.4 CLBWORKS-29B Physical Works

Hypotheses associated with physical works have been grouped because physical works have not yet been implemented at this stage in the project. Several potential wildlife physical works were identified (Hawkes and Howard 2012), but until they are implemented and monitoring is initiated to assess the response of wildlife to physical works, there is no need to assess each hypothesis individually.

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

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

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

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

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

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

Hawkes and Howard (2012) promoted three physical works projects that would increase the amount of shallow wetland habitat available in the drawdown zone of mid- and lower Arrow Lakes Reservoir. While these projects are purported to increase the suitability of the drawdown zone for wildlife (including amphibians, reptiles, songbirds, wetland-associated birds, arthropods, aquatic macrophytes, ungulates, large mammals, small mammals, medium-sized mammals, and bats), there are other prescriptions that were developed that will come at no cost to the Water Licence Requirements program, and that will improve habitat for wildlife immediately adjacent to the drawdown zone. For example, Hawkes et al. (2011a) reported that both Rubber Boa and Western Skink were documented on a rocky outcrop just above the drawdown zone at Edgewood North. In 2011 the Columbia Basin Fish and Wildlife Compensation Program conducted an investigation of this site and recommended that small diameter (< 15 cm) conifers be removed (via a slash and burn program) along with the manual removal of invasive weeds to improve the suitability of the site for both Rubber Boa and Western Skink (McKinnon and Hill 2011). This program should be implemented in 2012. Monitoring of the site pre-impact could be conducted as part of the currently scheduled field work for CLBMON-11B1 and as part of the field program for CLBMON-11B1 in 2013.

The monitoring program implemented to assess the effectiveness of the proposed physical works in Hawkes and Howard (2011) should be based on the program implemented for CLBMON-11B1; however, some revisions will be required. For example, a wetland monitoring component should be included and the need to aerial ungulate surveys should be revisited.

7.0 RECOMMENDATIONS

The recommendations included in the Year 2 (2010) annual report are provided below along with a brief indication of how they were implemented in Year 3 (2011).

1. Continue sampling songbirds, arthropods and mammals (including bats) using the methods implemented in 2010. However, several modifications are suggested:

i. Constrain arthropod sampling to the period from early May through mid-June to coincide with songbird sampling. Data show that arthropod species richness and diversity values peak during this period, so sampling beyond mid-June does not increase our ability to address the management questions.

This recommendation was implemented in 2011. Although the overall biomass of arthropods was lower than in 2010 (which could be a function of localized environmental conditions or natural variability), the timing of the sampling coincided with the songbird surveys. This provided a direct comparison of songbird species richness and relative abundance with the biomass of arthropods present during the time of songbird sampling. Arthropod sampling in 2013 should occur at the same time as songbird sampling and should follow the same methods used in 2011.

ii. Analyses associated with arthropods should continue to focus on biomass (Malaise traps only) and on changes in spider and beetle communities (pitfall traps). Buchholz (2010) provides a compelling review and convincing arguments for using spiders as a suitable model group to assess the effectiveness of habitat restoration in improving habitat quality. Further, analyses should focus on those orders of arthropods that are preyed on by songbirds.

This recommendation was implemented in 2011 and the utility of using spiders was further assessed. Results suggest that at least two (and possibly) three families of spiders could be effective indicators of habitat change associated with the revegetation prescriptions.

iii. Songbird sampling should be conducted between early May and mid-June. Dropping the late April sampling period will not affect our ability to detect all species at each reach. In 2010, all species detected in late April were also detected in early May.

This recommendation was implemented and produced a dataset comparable to that of 2010. Several species were not included in the analyses primarily because they were not documented within 75 or 30 m of the point count centre or because they were not detected in 2011), which was related to the natural (inherent) variability associated with songbird sampling and was not a reflection of the timing or methods used. The timing of songbird sampling in 2013 should align with the 2010 and 2011 sampling.

2. Sample size associated with revegetation prescriptions is limited in mid- and lower Arrow Lakes Reservoir. Give consideration to increasing sample size by sampling revegetation prescriptions applied in Revelstoke Reach, starting in 2011 (Table 5-3). This is the only way to increase sample sizes associated with revegetation effectiveness monitoring.

   Sampling in Revelstoke Reach could be problematic for two reasons: (1) the accessibility and use of the drawdown zone by the general public could put our sampling equipment (Malaise, pitfall, and light traps) at risk, and (2) songbirds are currently being sampled as part of CLBMON-39, which could potentially duplicate work already being done. Moreover, our presence could inadvertently influence the results of that program. Because of the proximity to Revelstoke and the use of the area by the public, we are reluctant to deploy our equipment in that area.

3. Develop wildlife physical works prescriptions in 2011. Monitoring methods, likely based on those used in this study and in CLBMON-11B4, should also be developed.

   Wildlife physical works were developed and submitted as a stand-alone report (Hawkes and Howard 2011).

4. Use the biophysical habitat map developed in 2010 to assess the potential distribution of suitable habitats for certain species on the conservation framework list (e.g., Western Skink and Rubber Boa), and develop habitat suitability ratings for ungulates (moose, elk, deer) and grizzly bears.

   This is proposed for 2013 after the collection of the third year of data.

Some additional recommendations stemming from the work completed in 2011 include:

1. **Consider modifying the sampling program of CLBMON-11B1 to occur annually.** It may be possible, within the existing budget, to implement CLBMON-11B1 on an annual basis. This approach would ensure that appropriate before-

and after-impact data are collected at the proposed physical works locations (i.e., Lower Inonoaklin Road, Edgewood South, and Burton Creek). Collecting songbird, arthropod, and ungulate data on an annual basis would also provide a better indication of the annual variability associated with those species groups and their use of the drawdown zone (with particular emphasis on the use of control and treatment sites). Once the proposed physical works are implemented, annual sampling at those locations would serve to assess the effectiveness of those physical works using a traditional before-after-control-impact (BACI) study design (Smith 2002).

2. **Revise sampling approach for CLBMON-11B1.** There is a need to revise the monitoring program developed for CLBMON-11B1 and CLBMPON-11B4 to ensure that monitoring assesses the effectiveness of the physical works in improving habitat suitability in the drawdown zone of mid- and lower Arrow Lakes Reservoir. For example, because all proposed physical works will increase the amount of shallow wetland habitat in the drawdown zone, sampling methods consistent with those used for CLBMON-11B4 (Hawkes et al. 2011c) should be considered.

3. **Reconsider the frequency of aerial surveys for ungulates.** Because the physical works are not intended to improve ungulate habitat directly (although we expect ungulates to use the wetland habitat), the applicability of conducting aerial surveys on a bi-annual basis should be reconsidered. It may be adequate to complete the aerial surveys in Year 5 (2013) and again in 2017 or 2019 (which is consistent with a typical 5-yearr window used to sample moose and other ungulates in other parts of the province).

4. **Bat Sampling.** The times that bat detectors turn on and off in the early morning sampling period should be adjusted so that the detectors turn off approximately 30 minutes before sunrise. In 2010 and 2011 the timing of sampling coincided with sunrise and 20 to 30 minutes after sunrise. This may have reduced the number of bat detections associated with the early morning period.

8.0 Additional Reporting Requirements

8.1 Data Deliverables

The following data deliverables have been or will be provided to BC Hydro and/or the Ministry of Environment to fulfill the Terms or Reference associated with CLBMON-11B1 or to fulfill the requirements of the wildlife sundry permit provided to LGL Limited for CLBMON-37 (which covers the capture and handling of amphibians and reptiles):

1.	Draft technical report	Submitted March 1, 2012
2.	300-word abstract	To be submitted with final report (April 30, 2012)
3.	Revised sampling protocol	To be submitted with final report (April 30, 2012)
4.	Copies of notes, maps, photos	To be submitted with final report (April 30, 2012)
5.	Digital appendix (Data)	To be submitted with final report (April 30, 2012)

8.1.1 Data Provided to BC Hydro

An MS Access database containing all 2009, 2010, and 2011 data will be provided with the final report. This database conforms to the standards established by the B.C. Ministry of Environment for wildlife species inventories.

8.1.2 Data Provided to the B.C. Ministry of Environment

Data collected under CLBMON-11B1 will be submitted to the Ministry of Environment, Ecosystems Information Section as per the requirements of the Terms of Reference associated with CLBMON-11B1 (and as per 2009 and 2010).

8.2 SARA-listed Species

Amphibians and Reptiles

The only amphibian at risk documented in the drawdown zone of Arrow Lakes Reservoir was the Western Toad, which is a species of Special Concern (as per SARA). The Columbia Spotted Frog (*Rana luteventris*) is currently a COSEWIC status report candidate species (as of October 2010). The status of this species remains not assessed, and populations are considered to be stable throughout its range.

Two species of reptiles with federal conservation status were documented in 2010, either in or near the drawdown zone of Arrow Lakes Reservoir:

1. The Intermountain–Rocky Mountain Population of the western Painted Turtle (*Chrysemys picta*) is blue-listed in British Columbia and is a federal species of Special Concern. This species has been documented using the drawdown zone of Arrow Lakes Reservoir in Revelstoke Reach from Airport Marsh south to 12 mile.

2. The Western Skink is blue-listed in British Columbia and is a federal species of special concern. This species was documented from the drawdown zone of Arrow Lakes Edgewood in the west-central portion of the reservoir.

Spiders

Several spider species of interest were recorded in 2010, including five new records for B.C.—Linyphiidae: *Glyphesis scopulifer*, *Grammonota gentilis*, *Pelecopsis mengei;* Theridiidae: *Euryopis argentea*; and Thomisidae: *Ozyptila sincere*—and one COSEWIC candidate species, an antrodiaetid folding door spider (Antrodiaetidae*: Antrodiaetus cerberus*). Although these records are exciting from the perspective of provincial biodiversity, they are not all that surprising given that little to no arthropod sampling has been done in this region of the province (Dr. Robb Bennett, Royal BC Museum, pers. comm.).

Arthropods

None of the butterflies or dragonflies documented in 2011 has federal designation; the twelve-spotted skimmer is blue-listed in BC.

Birds

No bird species with federal (COSEWIC) conservations status have been documented during songbird surveys; however, two species that are currently blue-listed in B.C. have been documented: Barn Swallow (*Hirundo rustica*) and Great Blue Heron (*Ardea herodias*).

Mammals

Grizzly bear is a species of Special Concern. This species was documented in the drawdown zone of Mosquito Creek and Edgewood South. The fringed myotis is currently blue-listed in B.C., but its federal status has been determined to be data deficient (last assessed in May 2004). This species was not documented in 2010. Townsend's big-eared bat (*Corynorhinus townsendii)*, which is blue-listed in B.C., was documented in one location (Edgewood North) in 2011.

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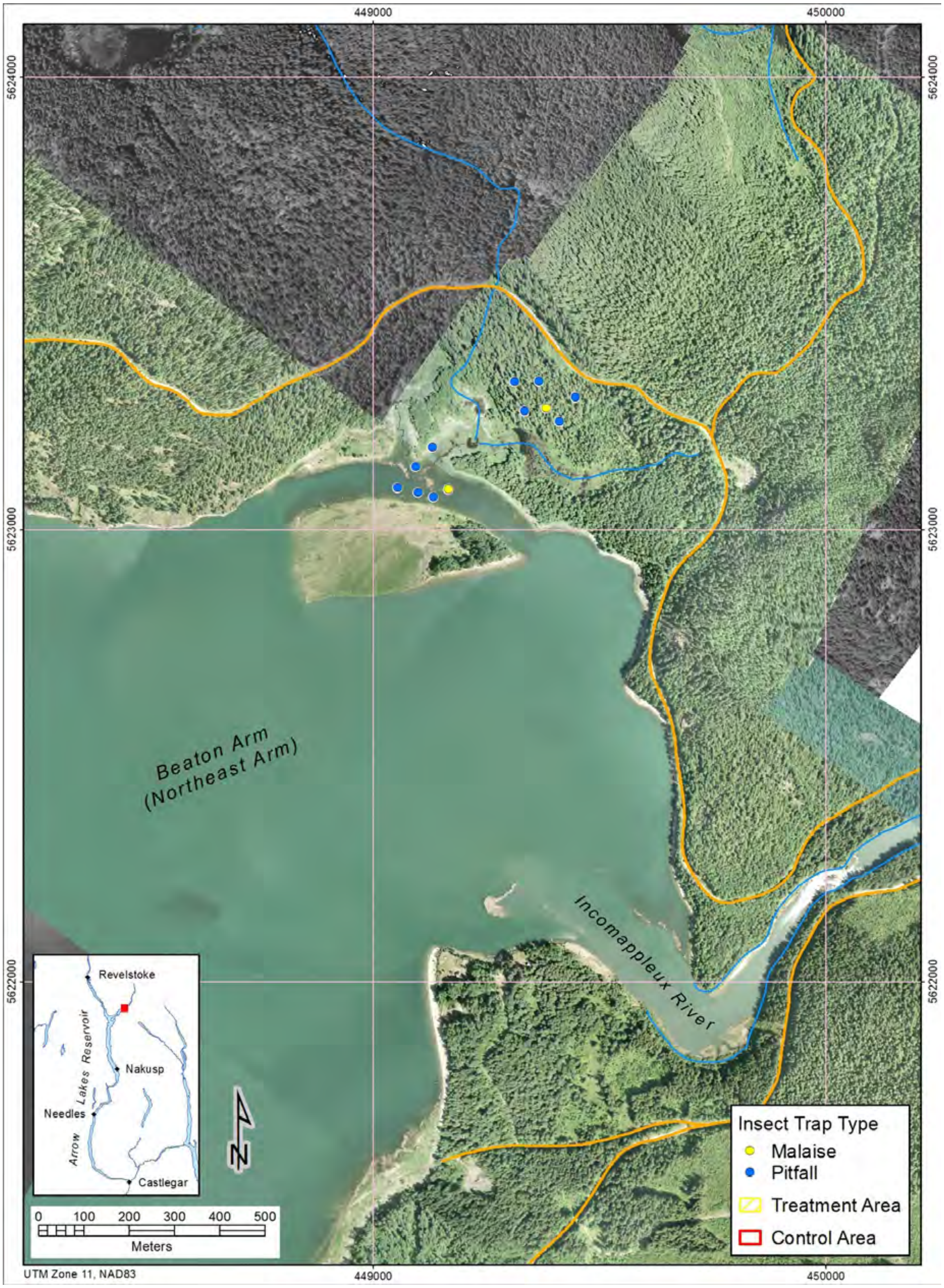
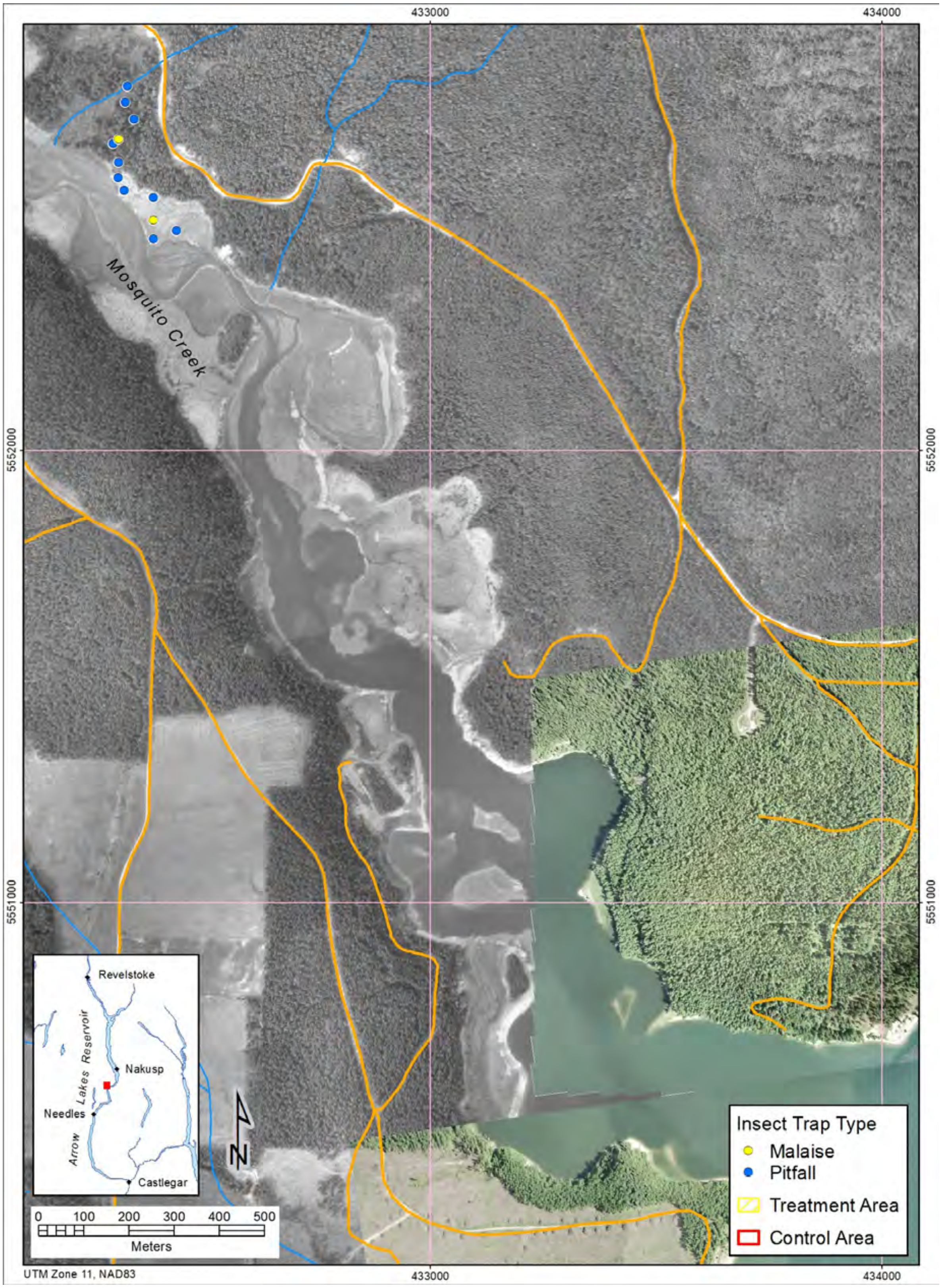
10.0 APPENDICES

10.1 Appendix 10-A: Maps depicting Malaise and pitfall trapping locations for all reaches sampled in 2011

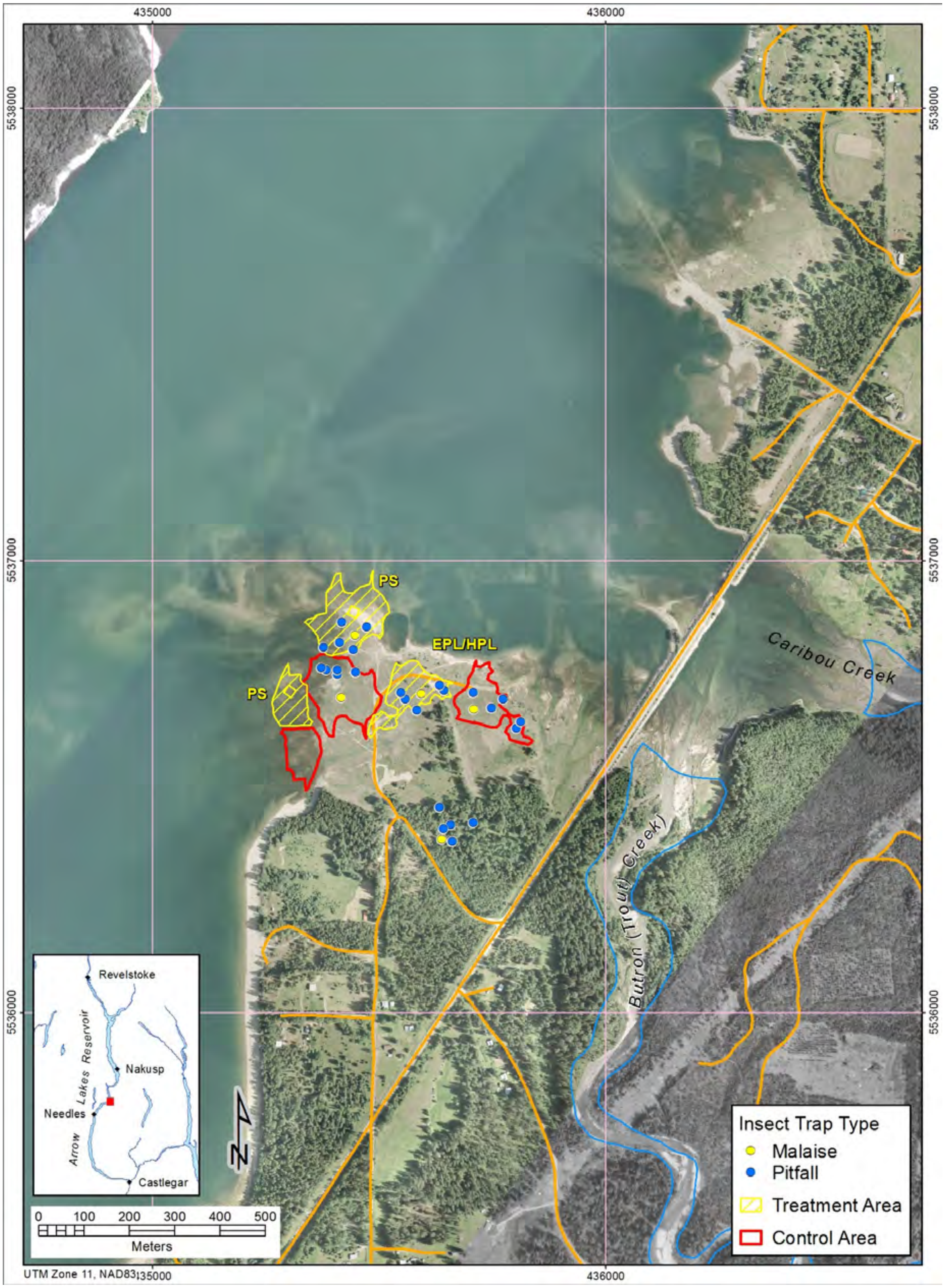


Map 10-1: Distribution of Malaise and pitfall traps installed at Beaton Arm, 2011

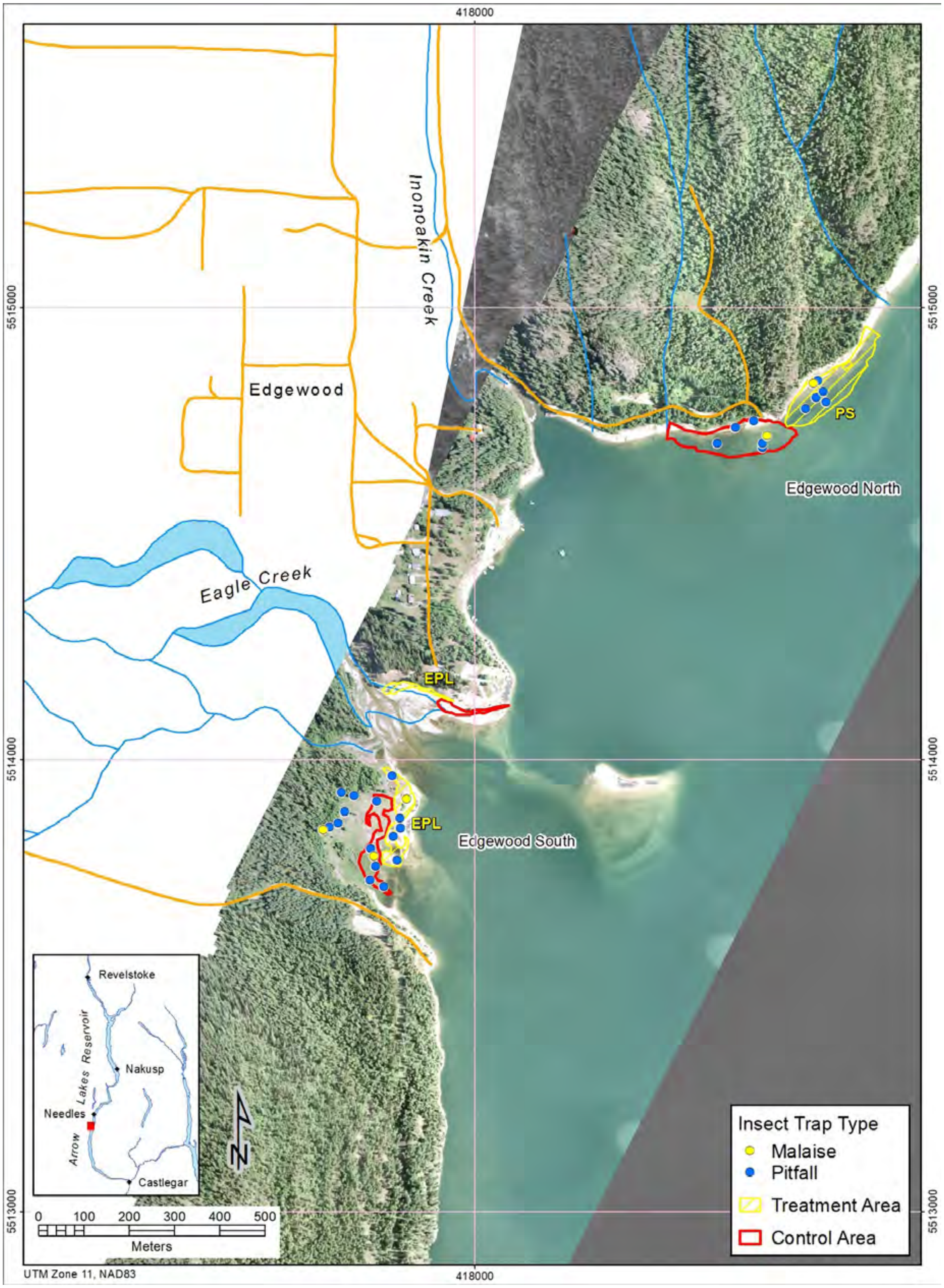
Map 10-2: Distribution of Malaise and pitfall traps installed at East Arrow Park, 2011



Map 10-3: **Distribution of Malaise and pitfall traps installed at Mosquito Creek, 2011**

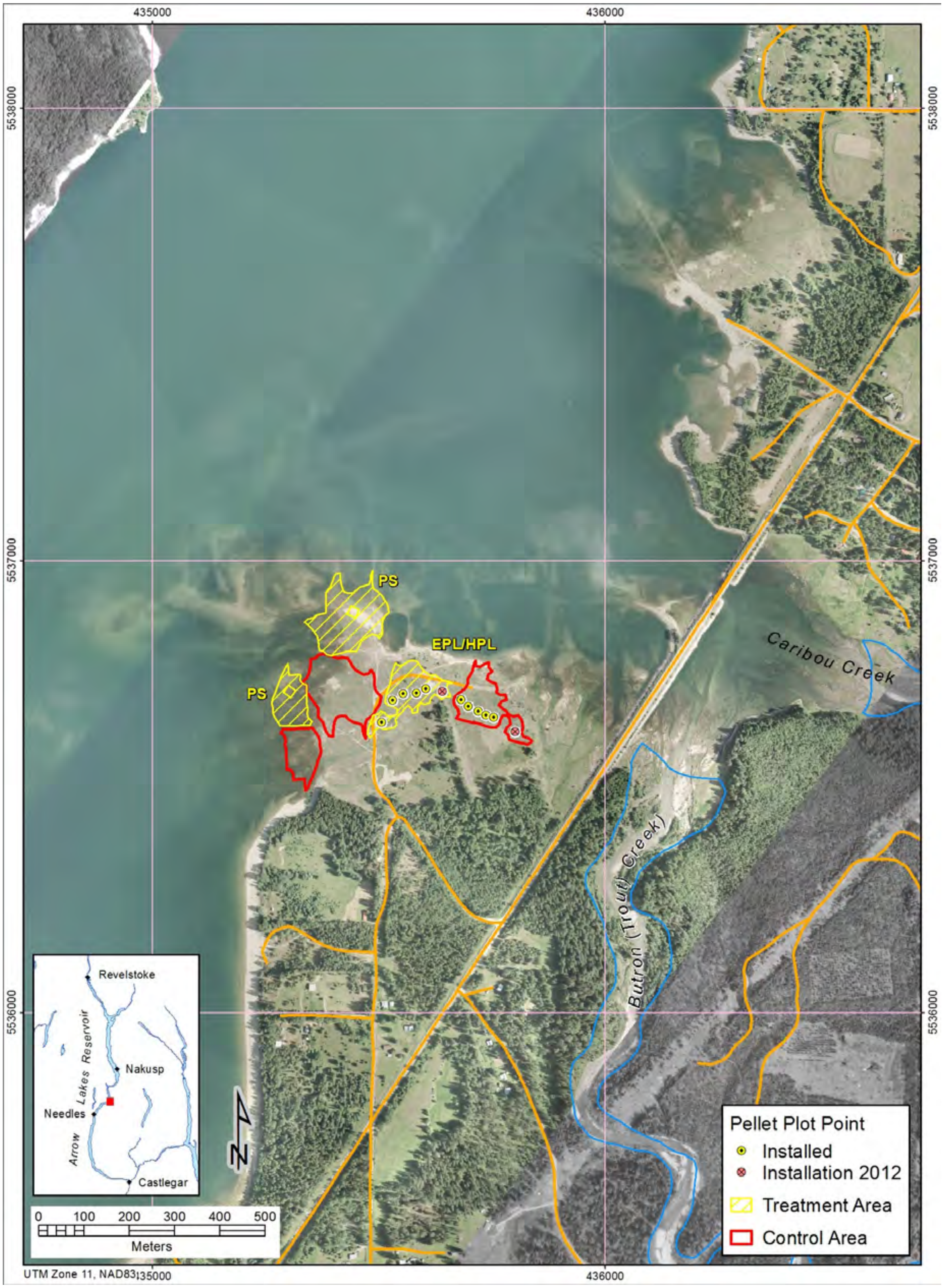


Map 10-4: **Distribution of Malaise and pitfall traps installed at Burton Creek, 2011**



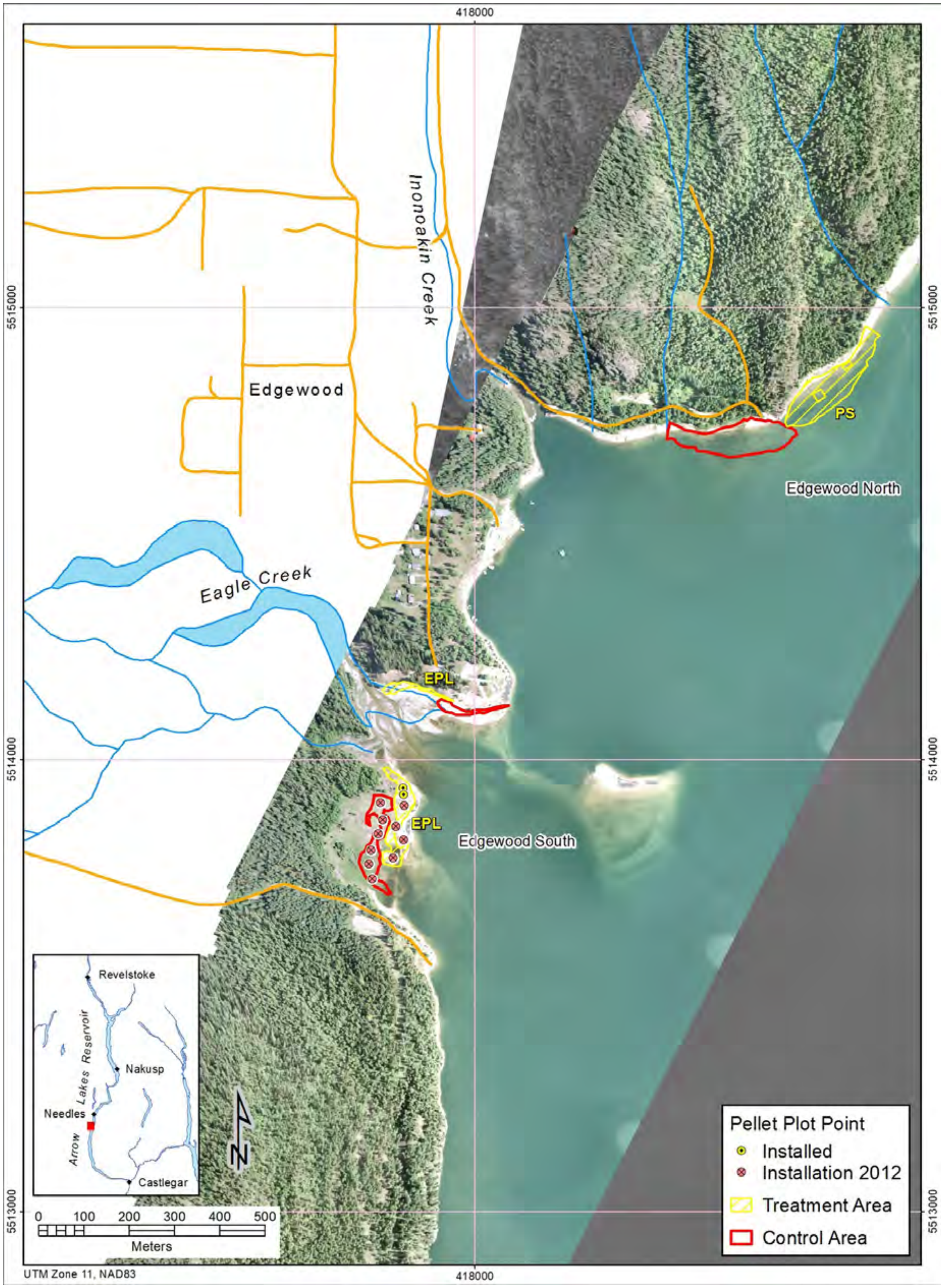
Map 10-5: Distribution of Malaise and pitfall traps installed at Edgewood North and South, 2011

10.2 Appendix 10-B: Maps depicting the location of circular pellet plots installed in 2011 or that need to be installed in 2012



Map 10-6: **Distribution of pellet plots that were installed in 2011 or that need to be installed in 2012 at Burton Creek**

Map 10-7: **Distribution of pellet plots that were installed in 2011 or that need to be installed in 2012 at Lower Inonoaklin Road**



Map 10-8: **Distribution of pellet plots that were installed in 2011 or that need to be installed in 2012 at Edgewood North and South**

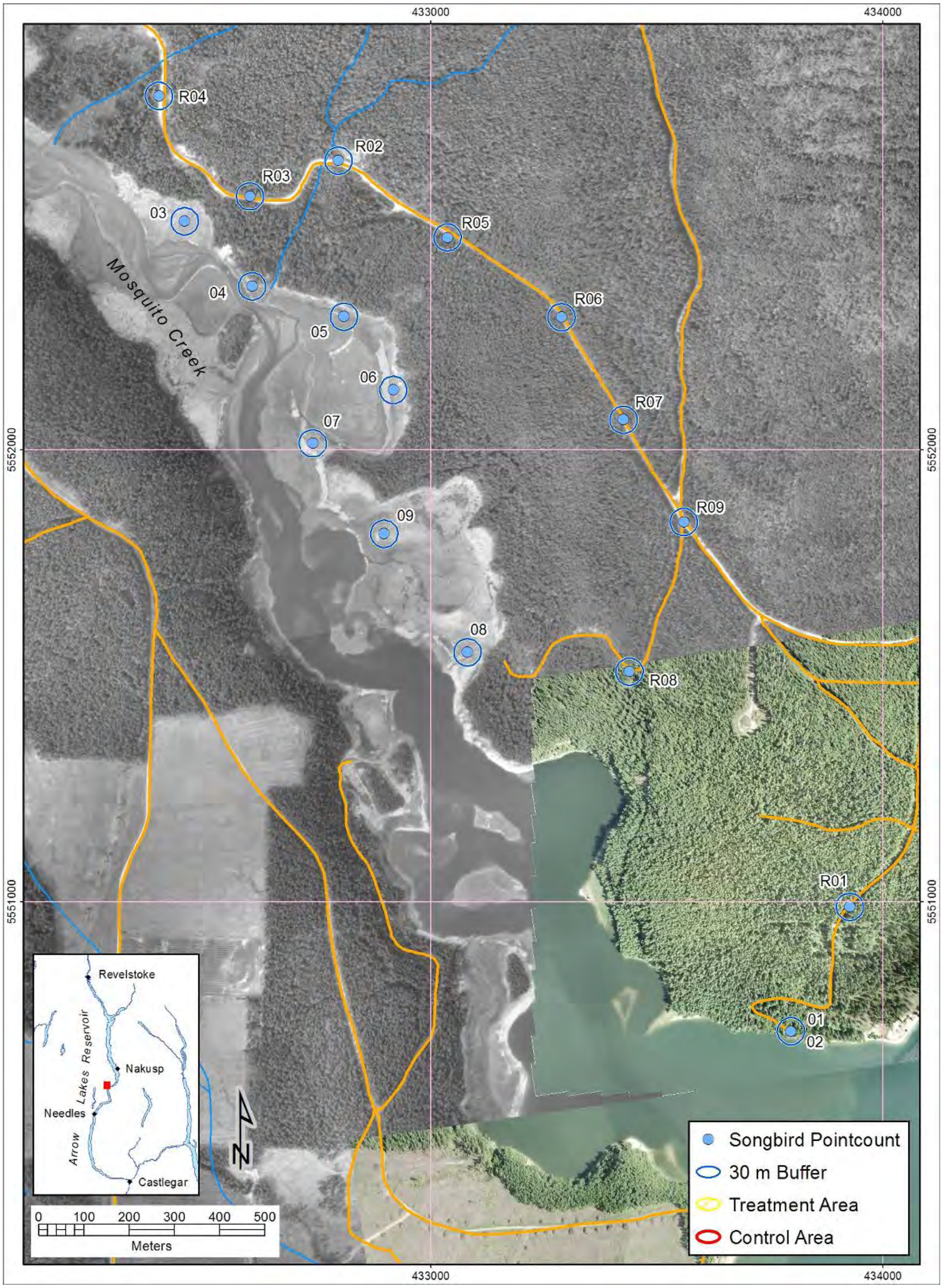
10.3 Appendix 10-C: Maps depicting the location of songbird point count stations for all reaches sampled in 2011

Map 10-9: Distribution of songbird point count stations at Beaton Arm, 2011

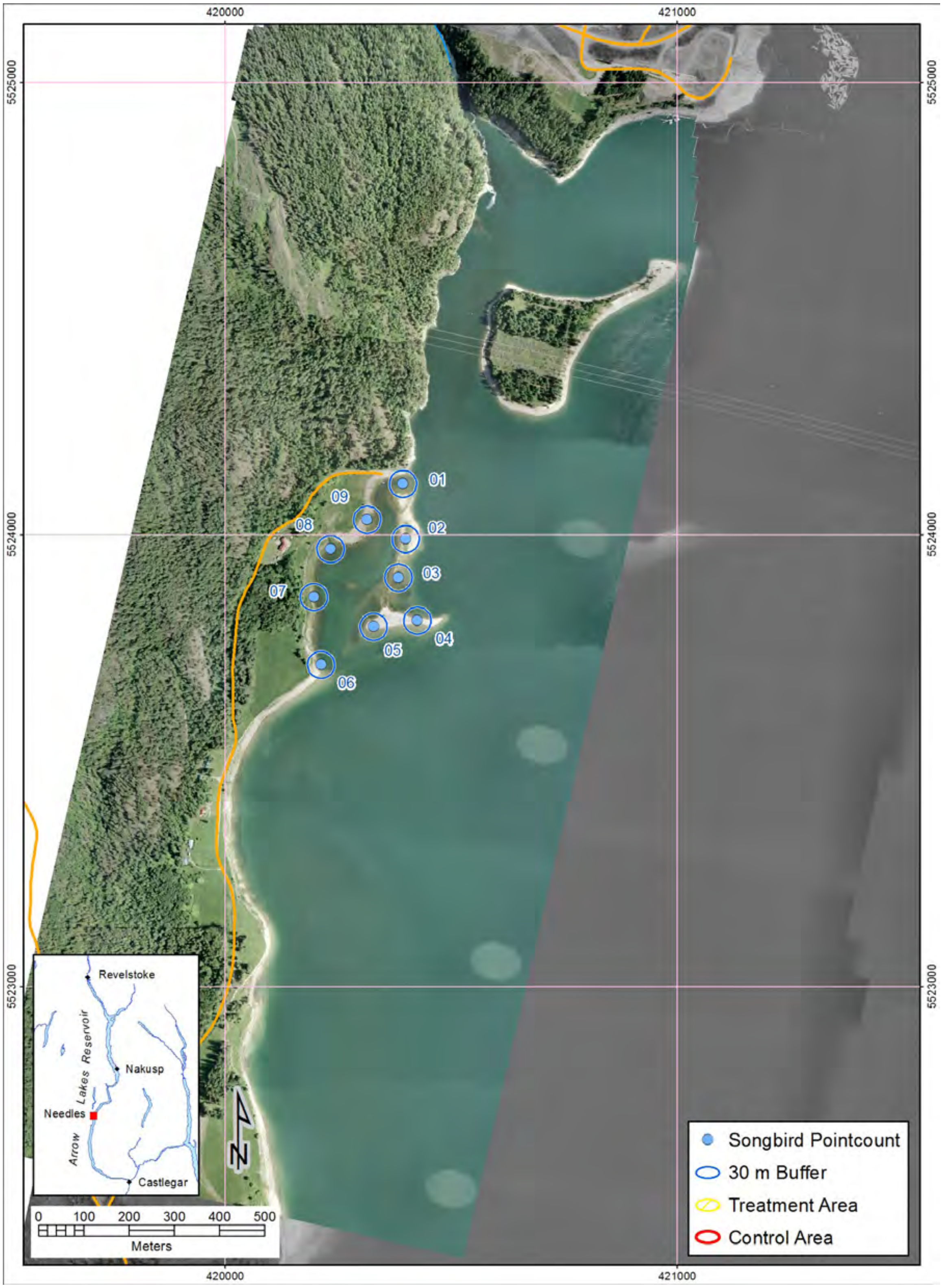
Map 10-10: Distribution of songbird point count stations at Burton Creek, 2011

Map 10-11: Distribution of songbird point count stations at East Arrow Park (north), 2011

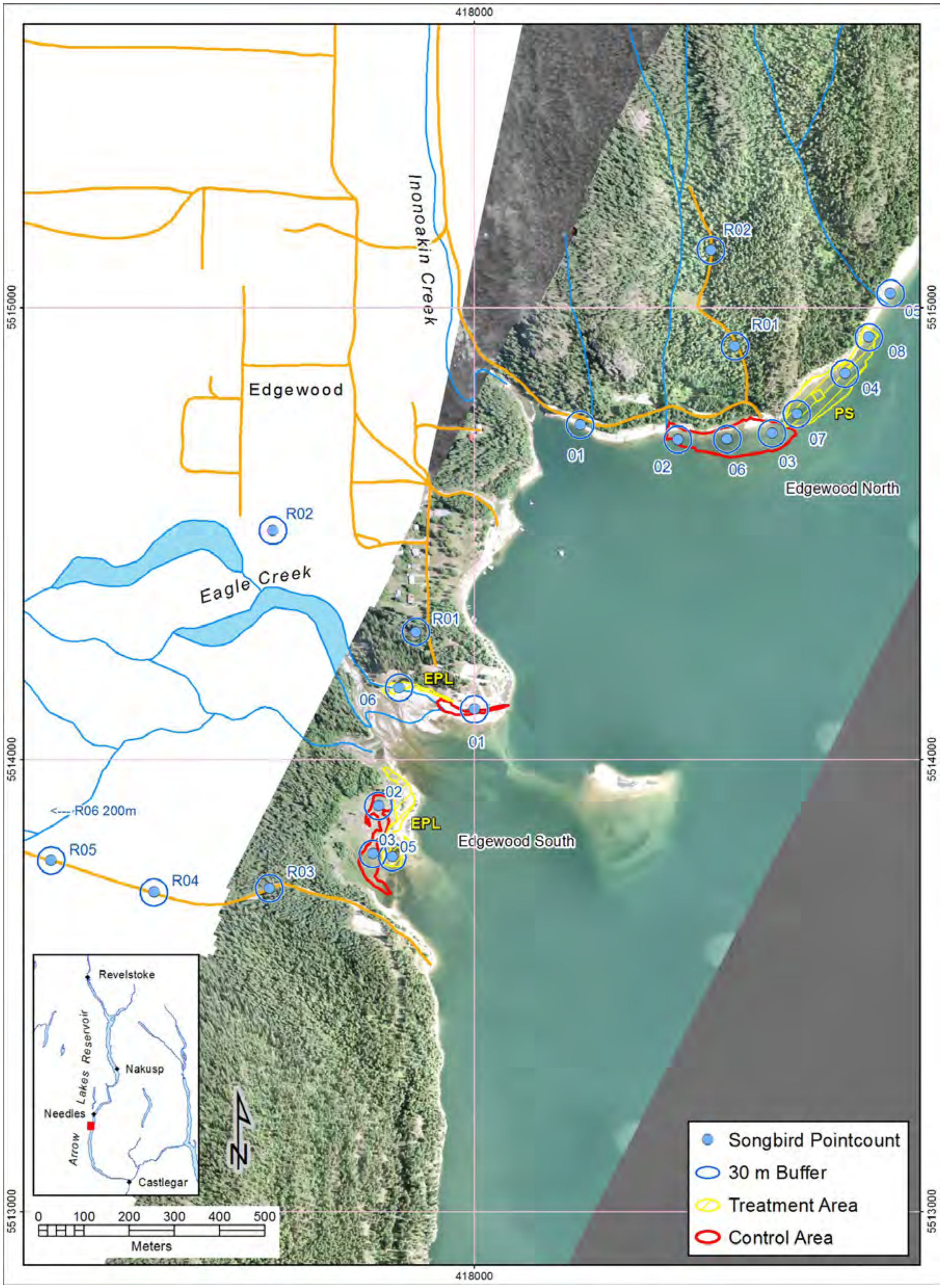
Map 10-12: **Distribution of songbird point count stations at East Arrow Park (south), 2011**



Map 10-13: Distribution of songbird point count stations at Mosquito Creek, 2011



Map 10-14: Distribution of songbird point count stations at Lower Inonoaklin Road, 2011



Map 10-15: **Distribution of songbird point count stations at Edgewood (north and south), 2011**

10.4 Appendix 10-D: Species of birds occurring at point count stations established in and adjacent to the drawdown zone of Arrow Lakes Reservoir in 2009, 2010, and 2011.

Table 10-1: Species of songbirds, swifts, swallows, and hummingbirds documented from the drawdown zone and adjacent upland habitats in 2009, 2010, and 2011

			2009							2010							2011							
Species Code	Common Name	Scientifc Name	BE	BU	EA	EN	ES	MC	Total	BE	BU	EA	EN	ES	MC	Total	BE	BU	EA	EN	ES	LI	MC	Total
ALFL	Alder Flycatcher	*Empidonax alnorum*															1							1
AMCR	American Crow	*Corvus brachyrhynchos*		2	3			1	6		6	1	1	5		13	1	1			1			3
AMGO	American Goldfinch	*Carduelis tristis*									1					1								
AMPI	American Pipit	*Anthus rubescens*								8	38	43	1	3	3	96	1	39				13		53
AMRE	American Redstart	*Setophaga ruticilla*	2	3	9	3	1	1	19	1	8					9	2		13	4		3	1	23
AMRO	American Robin	*Turdus migratorius*	3	6	40	2	7	7	65	17	31	57	23	5	38	171	9	9	26	4	16	2	22	88
BKSW	Bank Swallow	*Riparia riparia*				1			1		2	1				3								
BASW	Barn Swallow	*Hirundo rustica*		2	7		4		13	1	4	1	1			7						2		2
BLSW	Black Swift	*Cypseloides niger*									12					12								
BCCH	Black-capped Chickadee	*Poecile atricapillus*		1	2	4		1	8	4	17	18	20	1	15	75		1	5				2	8
BHGR	Black-headed Grosbeak	*Pheucticus melanocephalus*	3						3			1				1					1		1	2
BRBL	Brewer's Blackbird	*Euphagus cyanocephalus*					1		1															
BRCR	Brown Creeper	*Certhia americana*								1				3	3	7							2	2
BHCO	Brown-headed Cowbird	*Molothrus ater*			6				6		1	13	1	6	2	23			3	3	1	2		9
BUOR	Bullock's Oriole	*Icterus bullockii*		1	1				2									1				1	1	3
CAHU	Calliope Hummingbird	*Stellula calliope*										1				1								
CAFI	Cassin's Finch	*Carpodacus cassinii*	1						1															
CAVI	Cassin's Vireo	*Vireo cassinii*	3	1	4	1	2	5	16	4	1	9	2		7	23	7	1	10	4	1		5	28
CEWA	Cedar Waxwing	*Bombycilla cedrorum*		4	4			19	27	6	10					16			2				3	5
CBCH	Chestnut-backed Chickadee	*Poecile rufescens*	3		1			4	8				4	17	14	35	14		12	2	6		13	47
CHSP	Chipping Sparrow	*Spizella passerina*	9	12	12	2	3	11	49	8	27	14	2	9	9	69	5	18	15	11	9	4	18	80
CCSP	Clay-colored Sparrow	*Spizella pallida*									1					1								
CLSW	Cliff Swallow	*Petrochelidon pyrrhonota*									2			1	1	4						4		4
CORA	Common Raven	*Corvus corax*		3			2		5	1	6	4	3			14	1			2				3
COYE	Common Yellowthroat	*Geothlypis trichas*	8						8	7	2	1	3	5	2	20	5	1	10		5	6	2	29
DEJU	Dark-eyed Junco	*Junco hyemalis*	2	1	2	2	3	5	15	19	11	11	6	4	10	61	6	4	1	2	7		11	31
DUFL	Dusky Flycatcher	*Empidonax oberholseri*										2				2								
EAKI	Eastern Kingbird	*Tyrannus tyrannus*		1			1		2			1		2		3		1			1	5		7
EUST	European Starling	*Sturnus vulgaris*			5		2		7			8		5		13					3			3
EVGR	Evening Grosbeak	*Coccothraustes vespertinus*									1					1					1			1
GCKI	Golden-crowned Kinglet	*Regulus satrapa*	6		1			2	9	22	19	12	7	6	15	81	7		7		2		7	23
GRCA	Gray Catbird	*Dumetella carolinensis*		1	2	1			4										1					1
GRJA	Gray Jay	*Perisoreus canadensis*								2						2								
HAFL	Hammond's Flycatcher	*Empidonax hammondii*	24	8	20	5	9	20	86	18	13	19	6	6	18	80	12	4	22	10		1	17	66
HOLA	Horned Lark	*Eremophila alpestris*															1							1
HOFI	House Finch	*Carpodacus mexicanus*									1					1								
LALO	Lapland Longspur	*Calcarius lapponicus*																1						1
LZBU	Lazuli Bunting	*Passerina amoena*		4	2				6		1	1				2		3	2					5
LISP	Lincoln's Sparrow	*Melospiza lincolnii*						1	1	1						1			1			1		2
MACW	MacGillivray's Warbler	*Oporornis tolmiei*	9		2	1	1	3	16	4	1	1	2		2	10	5		3	1	2	3	3	17
MGNW	Magnolia Warbler	*Dendroica magnolia*						1	1														1	1
MOBL	Mountain Bluebird	*Sialia currucoides*									15	1				16							1	1
NAWA	Nashville Warbler	*Vermivora ruficapilla*				4	1	1	6			5	10	4		19				3	1		2	6
NRWS	Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	13	16	3	6	2	5	45	2	16	26	3	8	15	70				1		7		8
NOWA	Northern Waterthrush	*Seiurus noveboracensis*				1			1															
OCWA	Orange-crowned Warbler	*Vermivora celata*								1	2	2		1		6	1			1			1	3
PAWR	Pacific Wren	*Troglodytes pacificus*					1		1	8	3	5	2	2	7	27	12				1		4	17
PSFL	Pacific-slope Flycatcher	*Empidonax difficilis*	1	2					3											1				1
PISI	Pine Siskin	*Carduelis pinus*	1		14	4		5	24	22	4	13	3	6	19	67	20	1	5	1	1		8	36
RECR	Red Crossbill	*Loxia curvirostra*												16	7	23	22	9			2		2	35
RBNU	Red-breasted Nuthatch	*Sitta canadensis*	4	7	5	2	3	5	26	11	18	12	17	6	5	69	11	7	6	9	5	1	6	45
REVI	Red-eyed Vireo	*Vireo olivaceus*	1	5	5	2	2	3	18	1	4	1	2		1	9		2	4	2			1	9
RWBL	Red-winged Blackbird	*Agelaius phoeniceus*										1				1					1			1
RCKI	Ruby-crowned Kinglet	*Regulus calendula*								1	3		5		4	13	6		1		1		1	9
RUHU	Rufous Hummingbird	*Selasphorus rufus*	2		4		2		8	3	3	14	1	6		27		1	3	1	4		1	10
SAVS	Savannah Sparrow	*Passerculus sandwichensis*		1					1	6	23	14	3	6	2	54	2	18	3	3	49	11	2	88
SOSP	Song Sparrow	*Melospiza melodia*	4	1	5			1	11	4		6	1		3	14	7					2	5	14
STJA	Steller's Jay	*Cyanocitta stelleri*								1		3			2	6			1					1
SWTH	Swainson's Thrush	*Catharus ustulatus*	9	1	5	1	3	13	32	5	4			1	3	13	8		2	3	3		6	22
SWSP	Swamp Sparrow	*Melospiza georgian*															1							1
TOSO	Townsend's Solitaire	*Myadestes townsendi*											1			1								
TOWA	Townsend's Warbler	*Dendroica townsendi*					3		3	3		4		2	4	13	2			2	5			9
TRSW	Tree Swallow	*Tachycineta bicolor*	4	16	10	1	2	1	34		4	22	10	44	2	82						12		12
VATH	Varied Thrush	*Ixoreus naevius*	5		1				6	6	1	6	2	2		17	11			1	1		3	16
VASW	Vaux's Swift	*Chaetura vauxi*	9	3	6				18	92		15	5	11		123								
VEER	Veery	*Catharus fuscescens*			1			1	2						1	1								
VGSW	Violet-green Swallow	*Tachycineta thalassina*		2	13	9	5		29		2	61	16	42	5	126						7		7
WAVI	Warbling Vireo	*Vireo gilvus*	8	1	11	3	1	4	28	2		6	1	2	1	12	3		5	4	1		1	14
WEKI	Western Kingbird	*Tyrannus verticalis*										1				1		1						1
WEME	Western Meadowlark	*Sturnella neglecta*		2					2		12	4	1			17			1					1
WETA	Western Tanager	*Piranga ludoviciana*	1		2	1		2	6	1		3	1			5		1	2	1			1	5
WWPE	Western Wood-Pewee	*Contopus sordidulus*			1	1			2	1	1			1	1	4		2		1				3
WCSP	White-crowned Sparrow	*Zonotrichia leucophrys*									1		1	1	8	11					11			11
WTSP	White-throated Sparrow	*Zonotrichia albicollis*																			1			1
WWCR	White-winged Crossbill	*Loxia leucoptera*								1						1								
WIFL	Willow Flycatcher	*Empidonax traillii*	2	3	1				6								1							1
WIWA	Wilson's Warbler	*Wilsonia pusilla*	1						1	1	1		1	1	3	7		1	2	1	2			6
YEWA	Yellow Warbler	*Dendroica petechia*	2	1	4	1	2		10			3	4		1	8		1	2	4		2	1	10
YHBL	Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*									1					1								
YRWA	Yellow-rumped Warbler	*Dendroica coronata*	5	11	9	6	4	4	39	11	33	48	67	9	32	200	22	19	14	12	6		15	88
		Total Detections	**145**	**122**	**223**	**64**	**67**	**126**	**747**	**307**	**367**	**495**	**239**	**249**	**265**	**1922**	**206**	**147**	**184**	**94**	**151**	**89**	**170**	**1041**
		Total Species	**29**	**30**	**36**	**24**	**25**	**26**	**53**	**38**	**44**	**45**	**37**	**35**	**35**	**67**	**30**	**25**	**30**	**28**	**31**	**20**	**34**	**64**

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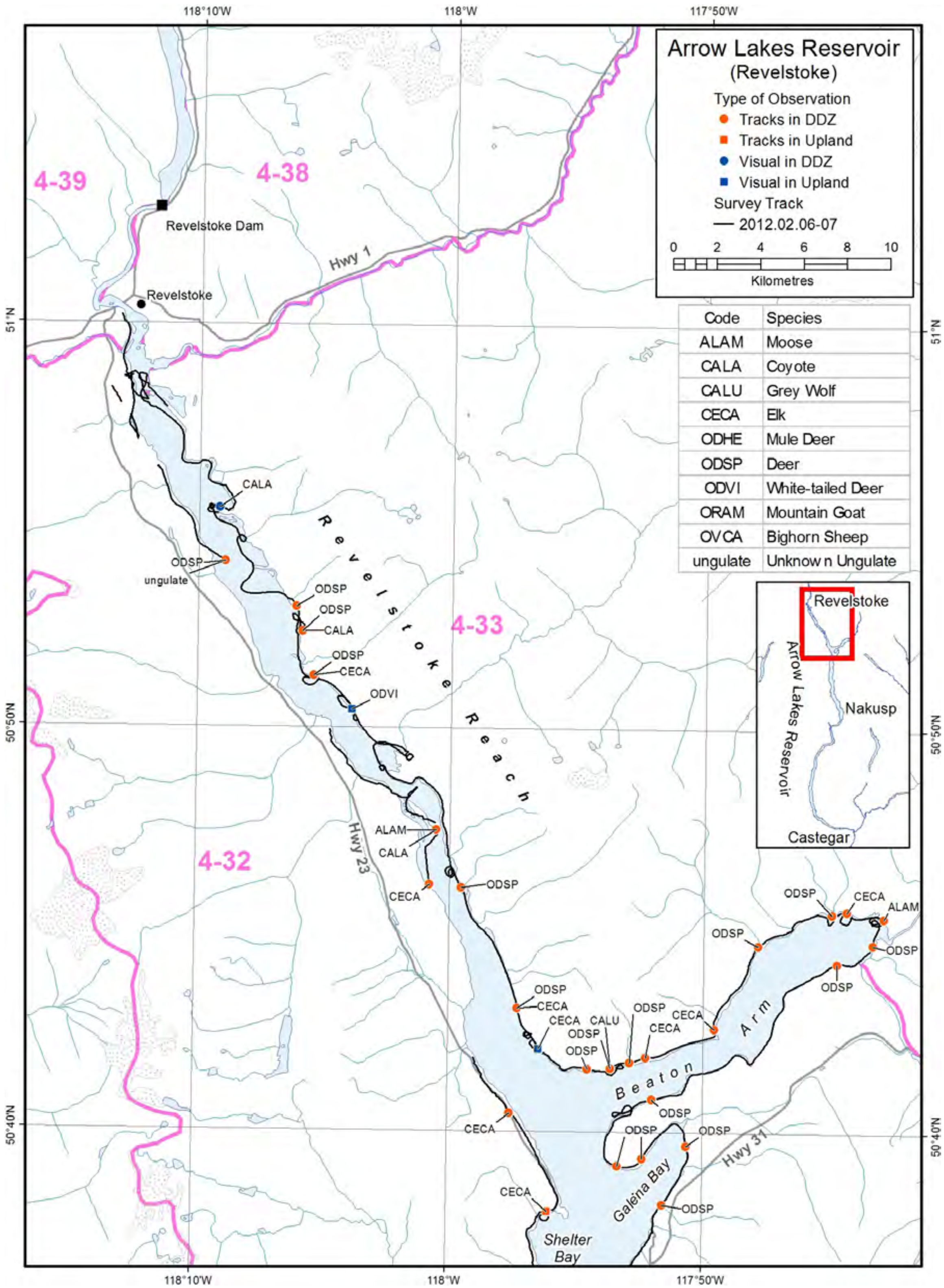
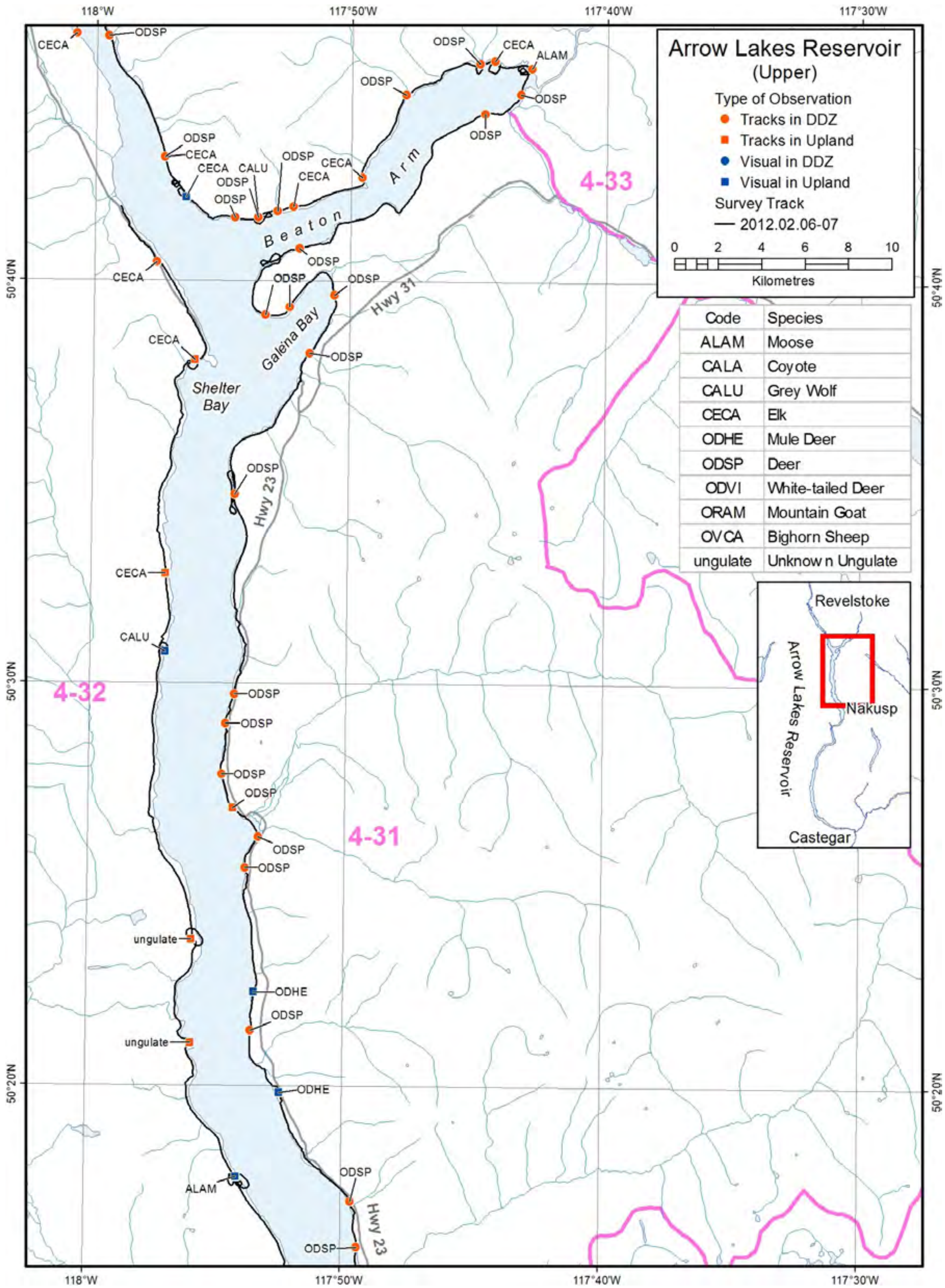
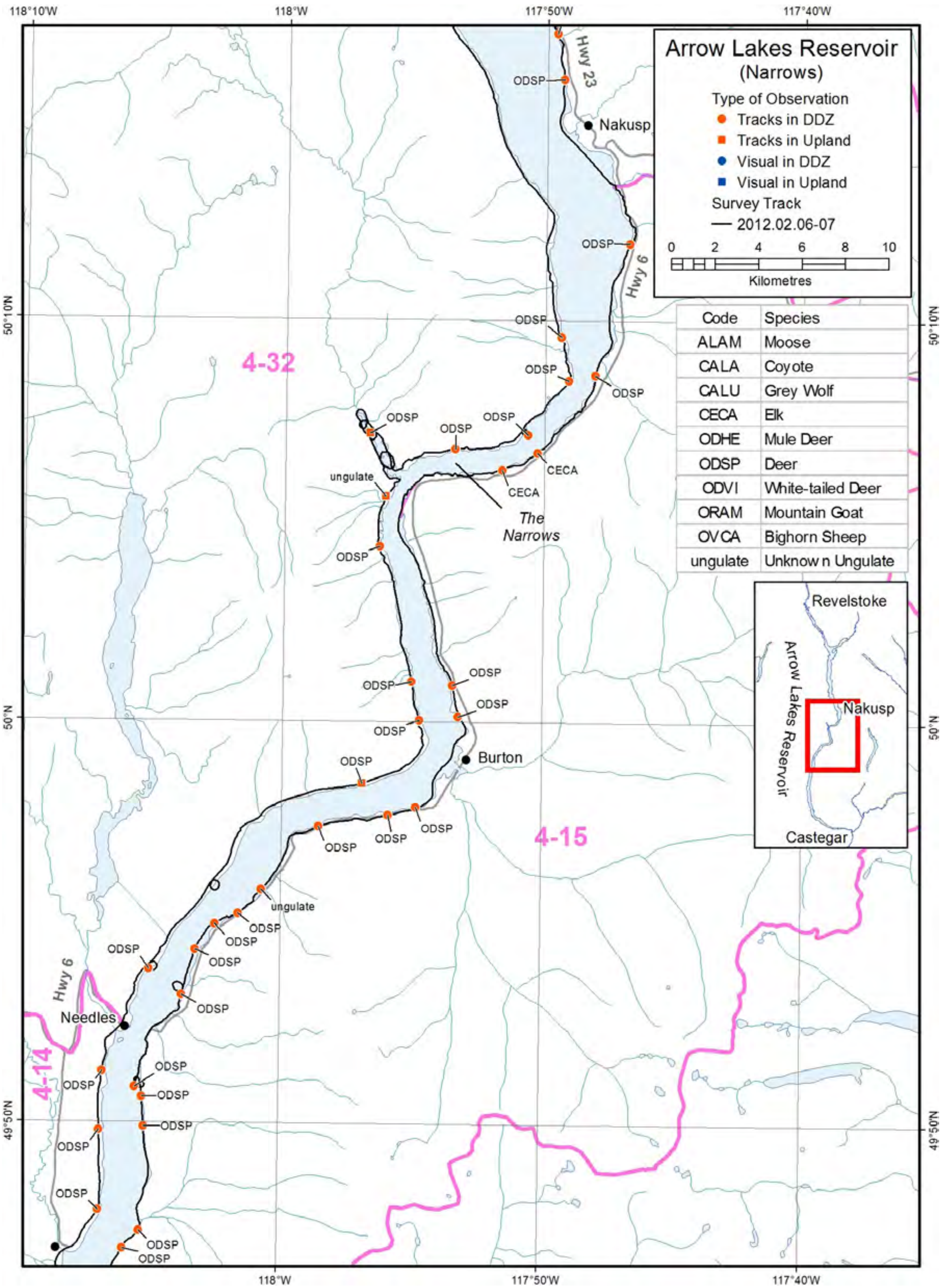
10.5 Appendix 10-E: Maps depicting the distribution of mammals and their sign observed during aerial surveys in February 2012



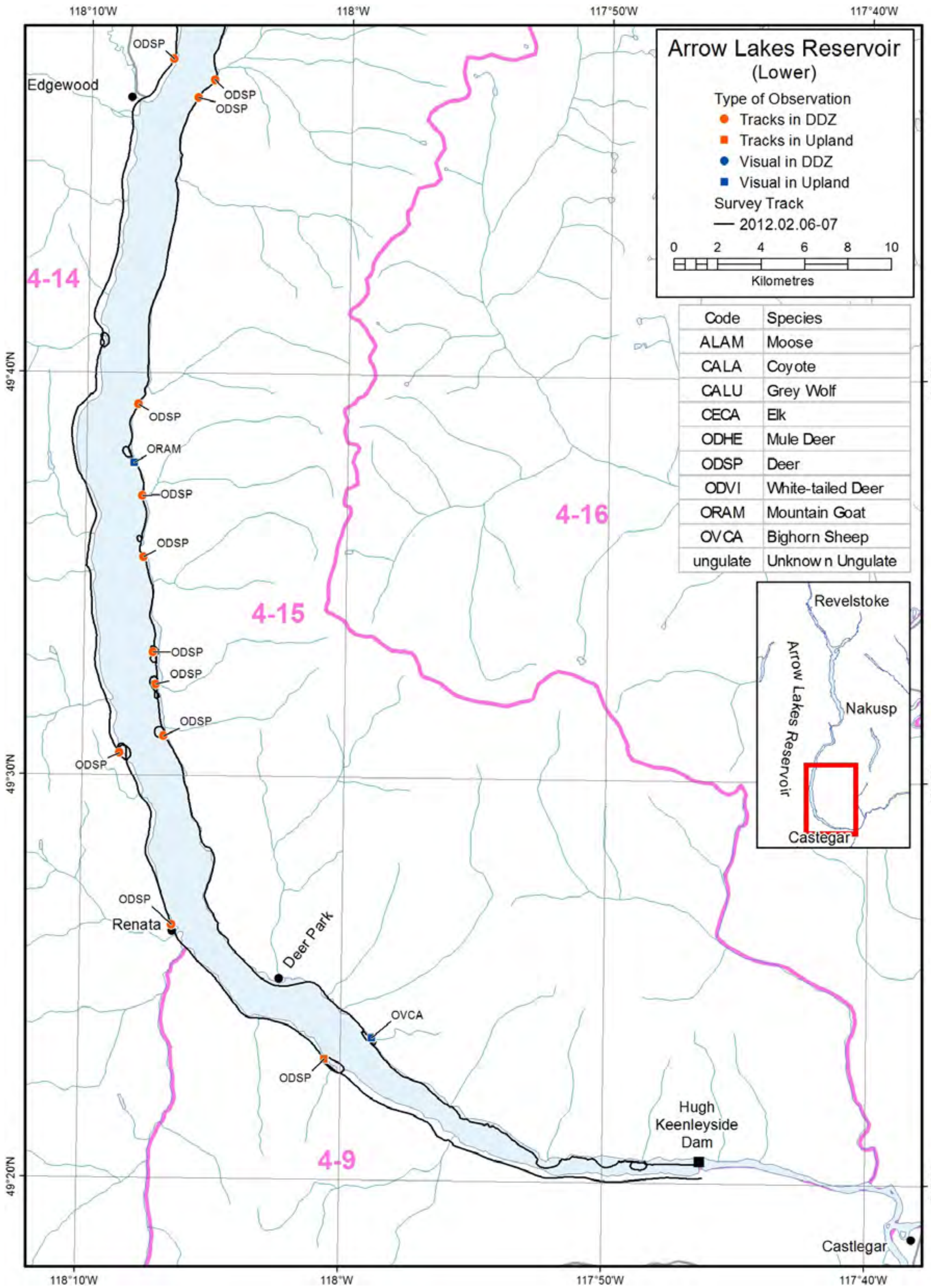
Map 10-16: Mammal observations in Revelstoke Reach made during survey February 2012. DDZ: drawdown zone



Map 10-17: Mammal observations in upper Arrow Lakes Reservoir made during February 2012. DDZ: drawdown zone



Map 10-18: **Mammal observations in mid- Arrow Lakes Reservoir made during February 2012.** DDZ: drawdown zone



Map 10-19: Mammal observations in lower Arrow Lakes Reservoir made during February 2012. DDZ: drawdown zone