Columbia River Project Water Use Plan

KINBASKET AND ARROW LAKES RESERVOIRS
REVEGETATION MANAGEMENT PLAN

Reference: CLBMON-9

Kinbasket Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis

Study Period: 2013

LGL Limited
environmental research associates
Sidney, BC

December 19, 2013

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KINBASKET AND ARROW LAKES RESERVOIRS REVEGETATION MANAGEMENT PLAN

Monitoring Program No. CLBMON-9
Kinbasket Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis




Year 4 – 2013 Annual Report
Final

Prepared for

BC Hydro Generation
Water Licence Requirements

Attention: Philip Bradshaw

BC Hydro Reference No. Q8-7956

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Columbia River Project Water Use Plan

Monitoring Program Terms of Reference

KINBASKET AND ARROW LAKES RESERVOIR REVEGETATION MANAGEMENT PLAN

CLBMON-9 Kinbasket Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis

December 19, 2013

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Cover photos: From left to right: looking north up Canoe Reach; Canoe wetlands; Mica Dam; Bush Arm in fall 2007. Photos © Virgil C. Hawkes.

EXECUTIVE SUMMARY

This year marked the fourth year of a proposed 10-year study to assess the effectiveness of revegetation treatments applied in the drawdown zone of Kinbasket Reservoir. This study aims to monitor the revegetation efforts associated with the CLBWORKS-1 program and inform on the effectiveness of these efforts in establishing vegetation communities within the drawdown zone. The revegetation of the drawdown zone through CLBWORKS-1 was initiated in 2008, and as of 2013, approximately 69 ha of the drawdown zone have been treated. The stated objectives of CLBWORKS-1 are: (1) to maximize plant species cover in the drawdown zone; (2) to increase plant species diversity in the drawdown zone; (3) to improve littoral productivity through increased plant diversity; (4) to improve shoreline stability; and (5) to protect known archaeological sites.

Repeating the research conducted in 2011 (Fenneman and Hawkes 2012), we resampled revegetation treatments stratified by geographic region, elevation, vegetation community type in the north, central, and south regions of Kinbasket Reservoir. Monitoring of existing vegetation areas (i.e., areas of natural vegetation within the same strata but not directly associated with the revegetation trials) also continued. However, assessment of the treated sites (and paired non-treated controls) remained the primary focus in 2013. Cover information was assessed for all species at each plot along with (where applicable) the survivorship of transplants from the 2008 to 2011 treatments. Plant biomass and soil samples were also collected at each treated site for laboratory chemical analysis.

Results from this study were consistent with previous (2011) findings: transplants have fared poorly overall in the drawdown zone, with survivorship of sedge seedling plugs declining to < 50 per cent on average after two years, and to < 10 per cent on average three or more years after planting. Virtually no deciduous stakes have survived over this time frame. Most transplanted plants were unable to cope with the combination of inundation timing, frequency, duration and depth, or with the by-products of these factors such as erosion, woody debris scouring, and drought conditions.

There was a general decrease in both total cover and species richness in treatment plots since 2011, mirroring a similar trend in control plots. We found no statistically significant differences between treatment and control plots either in per cent cover of vegetation, species richness, or species diversity within any plant community, elevation band, or region of the reservoir. It thus does not appear that either the quality or quantity of native vegetation in the Kinbasket Reservoir drawdown zone has increased as a result of the planting program.

The failure of revegetation efforts thus far to meet the stated remediation objectives suggests that changes are needed either to the planting program or the operating regime, or both. It is apparent from the 2013 assessment that without some level of adaptive management, the program will likely continue to struggle and any successes in establishing vegetation in the drawdown zone will be relatively minor. Nevertheless, we believe that opportunities exist for facilitating natural regeneration of drawdown zone vegetation through targeted

physical works such as woody debris removal, which could potentially yield greater benefits than the current planting program.

We provide several recommendations for future implementation years, ranging from ways to improve revegetation success and follow-up monitoring to suggestions for pursuing operational alternatives to planting as way of meeting reclamation objectives. Some key recommendations include:

1) Clarify long-term goals and interim project benchmarks to better track the progress of the planting program.
2) Focus future planting efforts on sites with demonstrated capability to support revegetation and on augmenting natural regeneration sites.
3) Explore the potential of woody debris removal for facilitating natural colonization and/or regeneration processes.
4) Consider alterations to reservoir operations that would create more predictable, more stable, and less detrimental flooding regimes.

KEYWORDS: Revegetation, drawdown zone, sedge, cottonwood, Kinbasket Reservoir, diversity, cover, effectiveness monitoring, reservoir elevation, treatment type, plug seedling, live stakes

CLBMON-9 Status of management questions and hypotheses

Management Question (MQ)	Management Hypotheses			Will MQ Be Addressed?	Data Required	Current Status	Preliminary Results
1. What is the quality and quantity of vegetation in revegetated areas compared to untreated areas, based on an assessment of species distribution, diversity, vigour, abundance, biomass, and cover?	H_{01A}	H_{01B}	H_{01C}	Yes	Field data (cover and biomass quadrats); lab data	Ongoing, but approaching ability to answer this MQ (anticipated response: “NO SIGNIFICANT DIFFERENCE”)	Some sedge plugs surviving in limited areas, but no significant differences detected in quality or quantity of vegetation between treated and untreated sites.
2. What are species-specific survival rates under current operating conditions (i.e., what are the tolerances of revegetated plant communities to inundation timing, frequency, duration and depth)?	H_{01A}			In part	Field data (survivorship data for different treatment types); controlled experimental data for separating out potentially confounding factors	Ongoing, but approaching ability to answer this MQ (anticipated response: “LOW TO ZERO SURVIVAL”)	Steep decline in survivorship of plug seedlings and live stakes each year following planting; ~4 per cent of plugs surviving 4 yrs. after planting; large-scale mortality of live stakes.
3. What environmental conditions, including the current operating regime (i.e., timing, frequency, duration and depth of inundation), may limit or improve the remediation and expansion of vegetation communities in the drawdown zone?	H_{01A}	H_{01B}	H_{01C}	Maybe	Field data, including time series data from CLBMON-10 (minimum of 5 years times series data), hydrological data	Ongoing, but approaching ability to identify limiting conditions (anticipated response: “THE CURRENT OPERATING REGIME IS THE MOST IMPORTANT, THOUGH NOT THE ONLY, VARIABLE LIMITING REVEGETATION SUCCESS IN THE DRAWDOWN ZONE”); several more years of field data, and likely a change in research direction, needed to identify environmental conditions (e.g., woody debris removal) that would improve remediation and expansion of vegetation communities	Under the current operating regime, revegetation success has been low and declining over time for all combinations of region, elevation, and planting prescription. Revegetation success of CLBWORKS-1 is likely limited by a combination of timing, frequency, duration and depth of inundation; erosion, sedimentation, and woody debris accumulation and scouring; choice of species used for revegetation; and choice of sites targeted for revegetation.

Management Question (MQ)	Management Hypotheses			Will MQ Be Addressed?	Data Required	Current Status	Preliminary Results
4. What is the relative effectiveness of the different revegetation treatments, as applied through CLBWORKS-1, at increasing the quality and quantity of vegetation in the drawdown zone?			H_{01C}	Maybe	Field data (cover and biomass quadrats, survivorship plots); lab data	Ongoing, but approaching ability to answer this MQ (anticipated response: “ALL ARE INEFFECTIVE”); statistical assessment hampered by small sample sizes and lack of replication/stratification associated with CLBWORKS-1. A review of the effectiveness of the current revegetation program is presented in this report	Widely variable results among individual sites and treatments, but the sedge plug treatment (PS) appears to be the only treatment type to have achieved moderate success in limited locales.
5. Does implementation of the revegetation program result in greater benefits (e.g., larger vegetated areas, more productive vegetation) than those that could be achieved through natural colonization alone?	H_{01A}	H_{01B}	H_{01C}	Maybe	Time series field data (including data from CLBMON-10) specifically targeting natural colonization in response to physical works (no such data currently available)	Ongoing, but approaching ability to answer this MQ (anticipated response: “NO”). A review of the effectiveness of the current revegetation program is presented in this report.	There has been a small amount of moderately successful plug establishment in limited areas, indicating that the revegetation program has resulted in a minor net benefit with respect to size and productivity of some vegetated areas. However, opportunities may exist for facilitating natural colonization processes through targeted physical works that could potentially create greater benefits than the revegetation program. For example, reducing woody accumulation and taking other measures to promote natural regeneration may be a more effective long-term approach to achieving revegetation objectives than out-planting, as discussed in Sections 6.0 and 7.0 of this report.

Management Question (MQ)	Management Hypotheses			Will MQ Be Addressed?	Data Required	Current Status	Preliminary Results
6. Is there an opportunity to modify operations to more effectively maintain revegetated communities at the site level in the future?	H_{01A}	H_{01B}	H_{01C}	Maybe	Review of existing literature, past reports, and current status of the revegetation program; data on the effectiveness alternative shoreline management options	Ongoing, but approaching ability to answer this MQ (anticipated response: "NO"). It is unlikely that modifying operations at this point will have any desired effects, because the revegetation treatments have already largely failed.	Under the current operating regime, revegetation success has been low and declining over time for all combinations of region, elevation, and planting prescription. Preliminary results suggest that adjusting the timing and reducing the duration and depth of inundation could translate into increased success for future revegetation attempts.

H_{01A}: There is no significant difference in vegetation establishment (based on species distribution, diversity, vigour, biomass and abundance) at control versus treatment locations.
H_{01B}: There is no significant difference in the cover of vegetation in control versus treatment areas.
H_{01C}: There is no significant difference in the cover of vegetation communities and vegetation establishment (based on species distribution, diversity, vigour, biomass and abundance) arising from different revegetation prescriptions.

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1.0 INTRODUCTION

Natural seasonal flooding of rivers and lakes creates or influences a variety of riparian plant communities (Junk et al. 1989; Johnson 2002; Nilsson and Svedmark 2002). These floodplain communities have disproportionately high biodiversity that in turn provides high quality habitat for many wildlife species across a wide range of taxa (Naiman and Décamps 1997; Johnson 2002; Hawkes and Gregory 2012). The construction of dams, however, has transformed most of the world's large rivers. By the end of the 20th century, about 45,000 large dams (at least 15 m in height) had been built on rivers worldwide (WCD 2000). While dams can provide several benefits such as flood control, power generation and management of water supply for irrigation, industrial use and urban consumption (Poff et al. 1997; Wu et al. 2004), they are also associated with numerous environmental impacts. Dams act as physical barriers to fish movement and plant hydrochory (water-based dispersal), trap fine sediment, and typically disrupt a river's natural flood pulse flow regime (Poff et al. 1997; Nilsson and Berggren 2000; Nilsson and Svedmark 2002). These effects impact upstream and downstream habitat, and alter numerous ecological processes that sustain both terrestrial and aquatic biodiversity (Nilsson and Berggren 2000; Johnson 2002; Wu et al. 2004).

Two major hydrological changes generally occur with dam construction. First, downstream water flow regimes can be produced that are quite different from undammed rivers because of diurnal and seasonal variations in demands for water or power (Nilsson and Berggren 2000). The changed flow regimes often result in substantially altered shorelines, vegetation changes, and declines in native aquatic species (Junk et al. 1989; Hill et al. 1998; Johnson 2002; New and Xie 2008). Secondly, dams create reservoirs that modify water level fluctuations and permanently flood areas upstream of the dam (Hill et al. 1998; Nilsson and Berggren 2000). This generally leads to loss of the original plant community as existing shorelines are submerged, and requires new shoreline vegetation to develop at higher elevations that often have poor soils without riparian seed banks (Hill et al. 1998; Johnson 2002; New and Xie 2008). For example, Yang et al. (2012) reported a decrease of 73.49%, 70.41% and 57.04% in vegetation family, genera and species respectively within the Three Gorge Dam drawdown area compared to pre-dam surveys. An additional upstream change is replacement of a stabilized shoreline with a new, erodible shoreline (Hill et al. 1998).

Reservoirs, particularly those associated with hydroelectric power generation, are usually managed to maintain water levels with regulated minimum and maximum levels. The "drawdown" zone consists of the exposed part of the shoreline below the top water line (Abrahams 2005). The environments occurring within a drawdown zone are generally challenging for most plant species. Although all water bodies experience some level of seasonal, annual or longer term fluctuations in water levels (known as the hydroperiod), these cycles typically follow predictable patterns to which the littoral plant species are adapted (Poff et al. 1997). For example, a freshwater body's typical hydroperiod is a flood event in the spring and early summer (the summer freshet) followed by low water in the late summer and early fall (Abrahams 2006). The receding shorelines provide habitat for a number of plant species over the course of the growing season, many of which are specifically adapted to these habitats. Conversely, in reservoir systems, water levels are typically maintained at low levels throughout the winter and spring to allow spring freshet waters to be captured. Thus, water levels actually tend to rise (often dramatically) throughout the spring and summer, inundating vegetation as it attempts to grow (Abrahams 2006).

Reservoirs managed for hydro-electric power typically have extreme fluctuations in water levels with associated drawdown zones measured in tens of metres (Abrahams 2005; Lu et al. 2010). These water level fluctuations produce repeated cycles of succession that consist of disturbance, colonization and growth (Abrahams 2005). While high plant recruitment can occur during low reservoir levels, there is often high plant mortality when reservoir levels rise (Johnson 2002). The extreme magnitude of water fluctuation can lead to a decline in the species richness of all herbs, a loss of the rare plant component, and an invasion by exotics (Hill et al. 1998; Yang et al. 2012). Steep and unstable banks, long fetches with associated wave action that reduces the substrate's organic matter and prevents plant growth, low levels of soil nutrients, accumulating large woody debris and its associated scouring, and high rates of erosion and sediment deposition provide additional challenges to vegetation establishment in the drawdown zone (Johnson 2002; Abrahams 2005). For example, many plants in the 30 m drawdown zone of the Three Gorges Dam in China died, resulting in a mainly unvegetated drawdown zone that experienced soil erosion and landslides (Yang et al. 2012).

Kinbasket Reservoir in southeastern British Columbia is 216 km long and holds a licensed volume of 12 million acre feet (MAF)[1] (BC Hydro 2005). Water level elevations are managed under a regime that permits a normal annual minimum of 707.41 m above sea level (ASL) and a normal maximum of 754.38 m ASL—a difference of almost 47 m. The large variations in water levels result in only sparse vegetation cover throughout much of the drawdown zone, which in turn impacts ecosystem functioning, wildlife values, and aesthetics. These cumulative impacts on reservoir shoreline vegetation communities had not been addressed until BC Hydro entered into the planning process for the Columbia River Water Use Plan (WUP) in 2001. During this planning process, the WUP Consultative Committee (WUP CC) recognized the value of vegetation in improving aesthetic quality, controlling dust storms, protecting cultural heritage sites from erosion and human access, and enhancing littoral productivity and wildlife habitat (BC Hydro 2005). The WUP CC further recognized that the most promising opportunity for accomplishing these objectives lay in enhancing vegetation along the riparian/wetland interface because this is the only area likely to be substantially affected by changes in BC Hydro operations.

In lieu of operational changes, the WUP CC supported a reservoir-wide revegetation program for Kinbasket Reservoir to maximize plant growth in the drawdown zone (BC Hydro 2005). The program was proposed as a multi-year project to facilitate development of long-term ground cover. The challenges to

[1] MAF = million acre feet. An acre foot is a unit of volume commonly used in the United States in reference to large-scale water resources, such as reservoirs, aqueducts, canals, sewer flow capacity and river flows. It is defined by the volume of water necessary to cover one acre of surface area to a depth of one foot. Since the area of one acre is defined as 66 x 660 feet, the volume of an acre foot is exactly 43,560 cubic feet. Alternatively, this is approximately 325,853.4 U.S. gallons, or 1,233.5 cubic metres or 1,233,500 litres.

natural vegetation establishment in the drawdown zone described above also apply to replanted areas. As part of the water use planning process, a study was undertaken to identify areas with the highest potential for successful vegetation establishment (Moody and Carr 2003). While most of the shorelines of Kinbasket Reservoir appeared to be unsuitable for enhancement due to coarse substrates and steep slopes, 68 sites were found with existing plant cover, the two largest sites being Bush Arm (1,169 ha) and Canoe Reach (698 ha). An additional 1,802 ha of shoreline were identified as having either high or moderate potential for revegetation.

As a result of these findings, the program “Kinbasket Reservoir Revegetation Program Physical Works” (CLBWORKS-1) was initiated in 2007 to improve existing vegetation communities and replant currently barren areas within the upper portion (~741 to 754 m ASL) of the drawdown zone. A second program, “Monitoring of Revegetation Efforts and Vegetation Composition Analysis” (CLBMON-9), began in 2008 to evaluate the effectiveness of revegetation efforts conducted under CLBWORKS-1. An effectiveness monitoring program aims to determine how well management activities, decisions, or practices meet their stated objectives (Marcot 1998; Noon 2003). Thus the key to designing an effectiveness monitoring program is the selection of statistically testable response variables that allow the objectives of the management action to be quantitatively evaluated (Machmer and Steeger 2002). Various metrics associated with plant communities (e.g., biomass, abundance, cover) were assessed annually and compared between control and treatment plots to determine the overall effectiveness of revegetation to improve ground cover in the Kinbasket Reservoir drawdown zone.

This report describes the methodology and study design for monitoring changes in vegetation at the site scale, challenges and limitations of the study, and results of field data analyses for CLBMON-9 Year 4 (2013). A primary focus of this report is the summary of the effectiveness of revegetation efforts up to 2013, including both successes and failures. This considers (but is not limited to) factors such as pre-planting planning, sourcing of stock, planting methodologies and adaptive management. The report also provides recommendations that are intended to improve the program in subsequent years.

2.0 GOALS AND OBJECTIVES

The goals of CLBMON-9, as stated in the Request for Proposal (BC Hydro 2008), are as follows:

1) Determine the species composition (i.e., diversity, distribution and vigour) of existing vegetation communities (as classified by Hawkes et al. 2007) to identify species that have been successfully surviving long-term inundation.

2) Evaluate the cover, abundance and biomass of existing vegetation communities (as classified by Hawkes et al. 2007) relative to elevation in the drawdown zone (across the elevation gradient of 741–754 m ASL).

3) Monitor the response of existing vegetation communities at the local (site) level to the continued implementation of the normal operating regime for Kinbasket Reservoir and other environmental variables.

4) Assess the long-term effectiveness[2] of the revegetation program to expand the quality[3] (as measured by diversity, distribution and vigour) and quantity (as measured by cover, abundance and biomass) of vegetation in the drawdown zone for ecological and social benefits.

5) Assess the costs and benefits of the revegetation prescriptions applied under CLBWORKS-1 (Kinbasket Reservoir Revegetation Program Physical Works) by monitoring the response of revegetated communities to different treatments in the drawdown zone of the reservoir.

The CLBMON-9 program was designed for simultaneous monitoring of both revegetated sites and existing vegetation areas (i.e., areas of natural vegetation occurring within the same strata as, but not directly associated with, the revegetation trials). This study therefore focuses partially on trends occurring within existing vegetation, although this was not a primary component of the 2013 monitoring season. Observations of intra-community changes at the site scale will complement data gathered as part of CLBMON-10 (Kinbasket Reservoir Inventory of Vegetation Resources), which monitors inter-community changes in existing vegetation communities at the landscape scale over the same period.

The primary focus of the 2013 program was on monitoring the effects of revegetation efforts at the site scale through plot-based monitoring. Landscape-level monitoring of revegetation efforts is being conducted under CLBMON-10, which uses aerial photography interpretation and collection of field data to detect changes in the spatial extent and species richness of the vegetation communities classified for the drawdown zone of Kinbasket Reservoir. Together, data from CLBMON-9 and -10 will inform on the effectiveness of the revegetation program in maximizing vegetation growth in the drawdown zone and facilitating the development of long-term self-sustaining riparian vegetation.

[2] Monitoring the long-term effectiveness is the process of obtaining and analyzing repeated samples of the key variables after revegetation treatment to see if the treatments resulted in increased vegetation cover and/or species abundance, distribution, diversity and biomass in relation to the operating regime and other environmental variables.

[3] "Quality" is defined as a measure of how effectively the established/enhanced vegetation meets the interests expressed by the WUP CC, including improving aesthetic quality, controlling dust, protecting cultural heritage sites from erosion and human access, and enhancing littoral productivity and wildlife habitat.

2.1. Key Management Questions

The management questions for this monitoring program address the intra-community responses of existing vegetation in the drawdown zone of Kinbasket Reservoir to the continued implementation of the operating regime at the local (site) level. Although included in this report, the management questions regarding existing vegetation were not a primary focus of the 2011 field season. For revegetated areas, however, the management questions address whether the continued implementation of the current reservoir operating regime allows for the establishment and expansion of vegetation at the site level through a revegetation program in the drawdown zone of Kinbasket Reservoir. Furthermore, they address the effectiveness of the CLBWORKS-1 revegetation program to determine if it is meeting its stated objectives.

2.1.1. Existing Vegetation

Primary management questions for existing vegetation communities in the drawdown zone of Kinbasket Reservoir between elevation ~754 and 741 m ASL[4] are as follows (BC Hydro 2008):

1. What is the species composition (i.e., diversity, distribution and vigour) of existing vegetation communities, as defined by Hawkes et al. (2007), in relation to elevation in the drawdown zone?
2. What are the cover, abundance and biomass of existing vegetation communities, as defined by Hawkes et al. (2007) in relation to elevation in the drawdown zone?
3. How does the current operating regime affect the within-community quality and quantity (i.e., species cover, abundance, biomass, diversity and distribution within existing communities) of existing vegetation?
4. Is there a shift in community structure (e.g., species dominance) or a potential loss of existing vegetated communities that is attributable to environmental conditions, including the current operating regime (i.e., timing, frequency, duration and depth of inundation)?

2.1.2. Revegetated Areas

Primary management questions for revegetated areas in the drawdown zone of Kinbasket Reservoir between elevation ~754 and 741 m ASL (approximate) are as follows:

1. What is the quality and quantity of vegetation in revegetated areas compared to untreated areas, based on an assessment of species distribution, diversity, vigour, abundance, biomass and cover?
2. What are species-specific survival rates under current operating conditions (i.e., what are the tolerances of revegetated plant communities to inundation timing, frequency, duration and depth)?
3. What environmental conditions, including the current operating regime (i.e., timing, frequency, duration and depth of inundation), may limit or improve the

[4] Locations suitable for successful establishment and development of vegetation communities are usually above 741 m.

remediation and expansion of vegetation communities in the drawdown zone?

4. What is the relative effectiveness of the different revegetation treatments, as applied through CLBWORKS-1, at increasing the quality and quantity of vegetation in the drawdown zone?
5. Does implementation of the revegetation program result in greater benefits (e.g., larger vegetated areas, more productive vegetation) than those that could be achieved through natural colonization alone?
6. Is there an opportunity to modify operations to more effectively maintain revegetated communities at the site level in the future?

2.2. Management Hypotheses

The following management hypotheses and sub-hypotheses aim to test the management questions stated above.

2.2.1. Existing Vegetation

H_0: Changes within existing vegetation communities between elevation 754 m and 741 m in the drawdown zone of Kinbasket Reservoir, if they occur over the monitoring period, are unrelated to the continued implementation of the current operating regime.

H_{0A}: Changes in the area occupied by specific species assemblages within existing vegetation communities, if they occur, are not related to the operating regime (timing, frequency, duration and depth of inundation).

H_{0B}: Changes in species diversity, distribution and vigour within existing vegetation communities, if they occur, are not related to the operating regime (timing, frequency, duration and depth of inundation).

H_{0C}: Changes in species productivity (cover, abundance and biomass) within existing vegetation communities, if they occur, are not related to the operating regime (depth, duration, timing, frequency of inundation).

2.2.2. Revegetated Areas

H_{01}: Revegetation treatments between elevation 741 m and 754 m support continued natural recolonization of the drawdown zone.

H_{01A}: There is no significant difference in vegetation establishment (based on species distribution, diversity, vigour, biomass and abundance) at control versus treatment locations.

H_{01B}: There is no significant difference in the cover of vegetation in control versus treatment areas.

H_{01C}: There is no significant difference in the cover of vegetation communities and vegetation establishment (based on species distribution, diversity, vigour, biomass and abundance) arising from different revegetation prescriptions.

H_{02}: Reservoir operating conditions have no significant effect on vegetation establishment in revegetated areas between elevation 741 m and 754 m.

H_{02A}: Vegetation establishment (based on species cover, distribution, diversity, vigour, biomass and abundance) is not significantly affected by the timing of inundation at control and treatment sites.

H_{02B}: Vegetation establishment (based on species cover, distribution, diversity, vigour, biomass and abundance) is not significantly affected by the frequency of inundation at control and treatment sites.

H_{02C}: Vegetation establishment (based on species cover, distribution, diversity, vigour, biomass and abundance) is not significantly affected by the duration of inundation at control and treatment sites.

H_{02D}: Vegetation establishment (based on species cover, distribution, diversity, vigour, biomass and abundance) is not significantly affected by the depth of inundation at control and treatment sites.

3.0 STUDY AREA

The Mica Dam, located 135 km north of Revelstoke, British Columbia, spans the Columbia River and impounds Kinbasket Reservoir (Figure 3-1). Completed in 1973, the Mica Dam is one of the largest earth fill dams in the world and was built under the terms of the Columbia River Treaty to provide water storage for flood control and power generation. The Mica powerhouse has a generating capacity of 1,805 MW. Kinbasket Reservoir is 216 km long and has a licensed storage volume of 12 MAF (BC Hydro 2007). Of this, seven MAF are operated under the terms of the Columbia River Treaty. The normal operating elevation of the reservoir ranges from 754.38 to 707.41 m ASL. However, application may be made to the Comptroller of Water Rights for additional storage for economic, environmental or other purposes if there is a high probability of spill.

Two biogeoclimatic (BEC) zones are represented in the lower elevations of Kinbasket Reservoir: the Interior Cedar-Hemlock (ICH) zone and the Sub-Boreal Spruce (SBS) zone. Four subzone/variants characterize the ICH, and one subzone/variant characterizes the SBS zone (Table 3-1). Of the six variants listed in Table 3-1, all but the ICHvk1 and ICHmk1 occurred in all landscape units selected for sampling.

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

Zone Code	Zone Name	Subzone and Variant	Subzone/Variant Description	Forest Region and District
ICHmm	Interior Cedar – Hemlock	mm	Moist Mild	Prince George (Robson Valley Forest District)
ICHwk1	Interior Cedar – Hemlock	wk1	Wells Gray Wet Cool	Prince George (Robson Valley Forest District) and Nelson Forest Region (Columbia Forest District)
ICHmw1	Interior Cedar – Hemlock	mw1	Golden Moist Warm	Nelson Forest Region (Columbia Forest District)
ICHvk1[a]	Interior Cedar – Hemlock	vk1	Mica Very Wet Cool	Nelson Forest Region (Columbia Forest District)
ICHmk1[a]	Interior Cedar – Hemlock	mk1	Kootenay Moist Cool	Nelson Forest Region (Columbia Forest District)
SBSdh1	Sub-Boreal Spruce	dh1	McLennan Dry Hot	Prince George (Robson Valley Forest District)

[a] Not in all landscape units were sampled.

3.1. Physiography[5]

The Columbia Basin is situated in southeastern British Columbia. The basin is characterized by steep valley side slopes and short tributary streams that flow into the Columbia River from all directions. The headwaters of the Columbia River begin at Columbia Lake in the Rocky Mountain Trench. The river flows northwest along the Trench for about 250 km before it empties into Kinbasket Reservoir behind Mica Dam (BC Hydro 1983). From Mica Dam, the river continues southward for about 130 km to Revelstoke Dam and then flows almost immediately into Arrow Lakes Reservoir behind Hugh Keenleyside Dam. The entire drainage area upstream of Hugh Keenleyside Dam is approximately 36,500 km^2.

The Columbia River valley floor elevation extends from approximately 800 m ASL near Columbia Lake to 420 m ASL near Castlegar. Approximately 40 per cent of the drainage area within the Columbia River Basin is above 2000 m ASL. Permanent snowfields and glaciers predominate in the northern high mountain areas above 2500 m ASL; about 10 per cent of the Columbia River drainage area above Mica Dam exceeds this elevation.

Most of the watershed remains in its original forested state. Dense forest vegetation thins above 1500 m ASL and tree lines are generally at about 2000 m ASL. The forested lands around Kinbasket Reservoir have been and are being logged, with recent and active logging (i.e., between 2007 and 2011) occurring on both the east and west sides of the reservoir.

[5] From BC Hydro 2007 after BC Hydro 1983

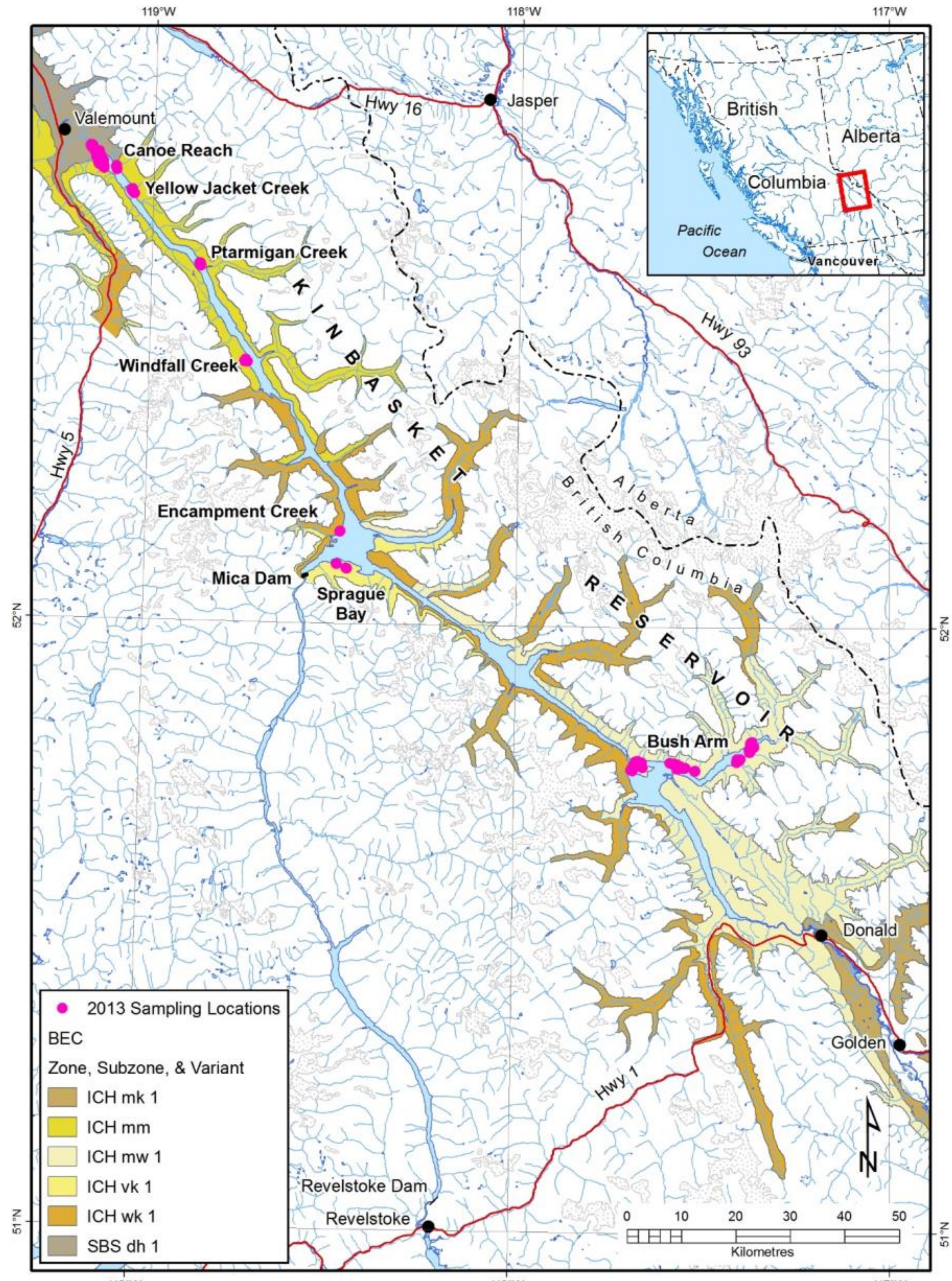

Figure 3-1: Location of Kinbasket Reservoir and vegetation sampling locations (pink). Landscape unit names (e.g., Bush Arm, Encampment Creek) were assigned to each area sampled in 2013. Refer to Table 3-1 for descriptions of biogeoclimatic (BEC) zones

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3.2. Climate[6]

Precipitation in the basin occurs from the flow of moist low-pressure weather systems that move eastward through the region from the Pacific Ocean. More than two-thirds of the precipitation in the basin falls as winter snow, resulting in substantial seasonal snow accumulations at middle and upper elevations in the watersheds. Summer snowmelt is complemented by rain from frontal storm systems and local convective storms.

Temperatures in the basin tend to be more uniform than does precipitation. With allowances for temperature lapse rates, station temperature records from the valley can be used to estimate temperatures at higher elevations. The summer climate is usually warm and dry, with the average daily maximum temperature for June and July ranging from 20°C to 32°C. The average daily minimum temperature in summer ranges from 7°C to 10°C. The coldest month is January, when the average daily maximum temperature in the valleys is near 0°C and average daily minimum is near -5°C.

During the spring and summer months, the major source of stream flow in the Columbia River is water stored in large snow packs that developed during the previous winter months. Snow packs often accumulate above 2000 m ASL through the month of May and continue to contribute runoff long after the snow pack has been depleted at lower elevations. Runoff begins to increase in April or May and usually peaks in June to early July, when approximately 45 per cent of the runoff occurs. Severe summer rainstorms are not unusual in the Columbia Basin. Summer rainfall contributions to runoff generally occur as short-term peaks superimposed upon high river levels caused by snowmelt. These rainstorms may contribute to annual flood peaks. The mean annual local inflow for the Mica, Revelstoke and Hugh Keenleyside projects is 577 m^3/s, 236 m^3/s and 355 m^3/s, respectively.

3.3. Habitats

Most of the study area (i.e., the upper portion of the drawdown zone between 741 and 754 m ASL) is comprised of steep slopes with cobble, gravel and sandy substrates. Areas that are less steep and/or are protected from the scouring action of coarse woody debris and waves allow for the accumulation of finer materials (e.g., silt, fine organic material) and support a wider variety of habitats, including grasslands, shrubs and wetlands dominated by swamp and marsh horsetail, various sedges, wool-grass, willows, common reed and rushes (see Hawkes et al. [2007] and Hawkes and Muir [2008] for a detailed description of habitat types).

The northern end of the reservoir, Canoe Reach, is ecologically sensitive due to presence of a vast peatland. The Valemount Peatland, near the town of Valemount, B.C., is situated entirely within the ICHmm. Historically, this peatland was likely a combination of sedge and horsetail fen and a swampy forest dominated by spruce (Ham and Menezes 2008; Yazvenko 2008, pers. obs.). Currently, most of its surface is covered by diverse plant communities ranging from typical wetlands (i.e., dominated by sedges, horsetails and other wetland

[6] From BC Hydro 2007 after BC Hydro 1983

plants) to more disturbed types dominated by non-wetland plants. Large areas are virtually devoid of vegetation and are covered by a mass of wood chips that are probably the result of the decay of floating logs (see descriptions in Hawkes et al. 2007). Other notable habitats in the northern end include wetlands and ponds on the gently sloping banks along the eastern side of the reservoir. The habitats around Mica Creek, including Sprague Bay and Encampment Creek, are composed primarily of low-gradient, silty flats or sloping shorelines of cobble and/or gravel.

The southern end of the reservoir includes mainly Bush Arm and the areas north of its mouth. It is characterized by an abundance of habitats on flat or gently sloping terrain that was created by sedimentation from Bush River and other inflowing streams. Another feature of these habitats is their protection from wind and wave action by the islands and peninsulas that protrude along the shoreline. This combination creates the largest variety of valuable habitats in the entire reservoir. Extensive fens and other wetlands have been identified in this area (Hawkes et al. 2007), and a high diversity of plants is supported by this variety of habitats.

For the purposes of CLMBON-9, we define three broad geographic areas within Kinbasket Reservoir: the south (Bush Arm), north (Canoe Reach), and central (Mica Creek [Figure 3-2 to Figure 3-7]). Sampling of existing vegetation was conducted in all three geographic regions in 2013, while revegetation sites were sampled in the south and north regions.

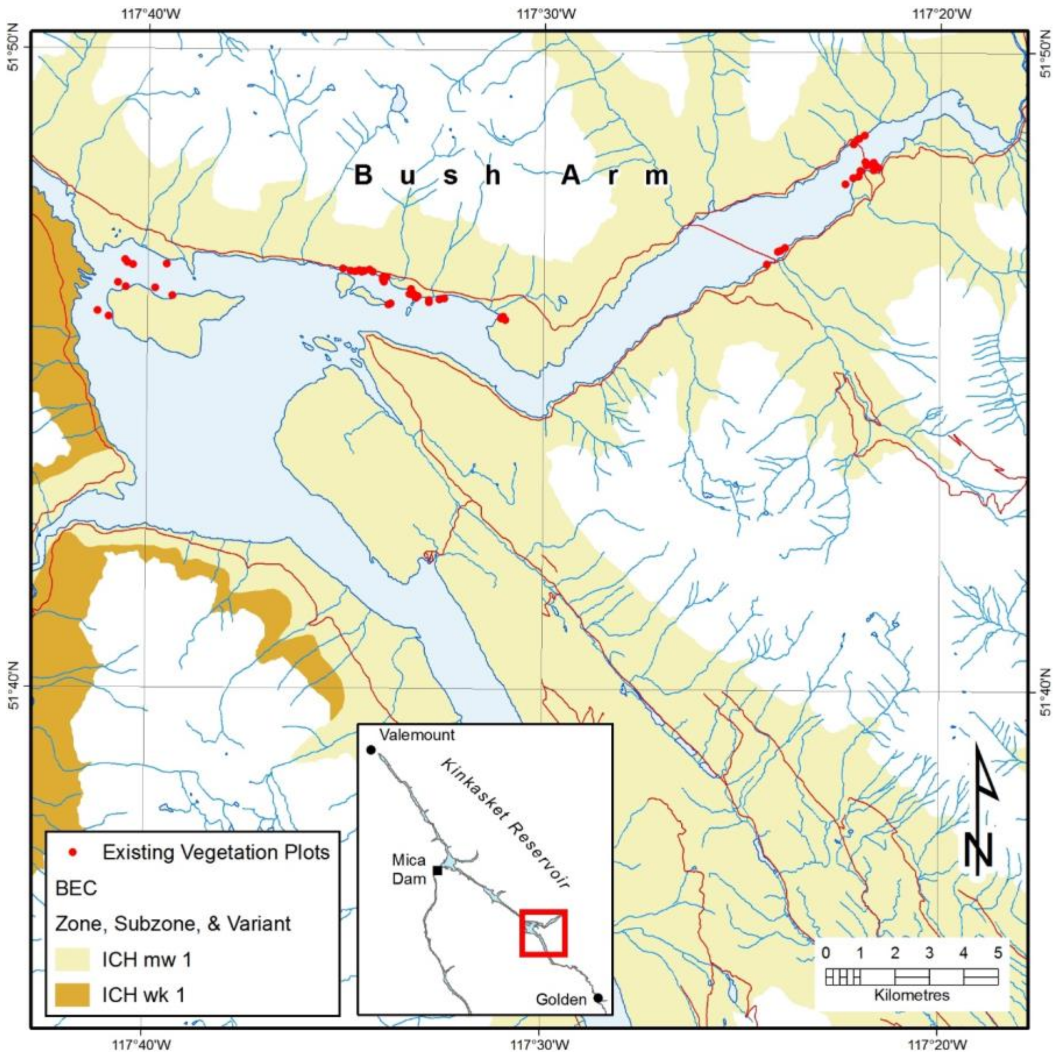

Figure 3-2: Locations of 2013 samples of existing vegetation in the south end of Kinbasket Reservoir. Refer to Table 3-1 for descriptions of biogeoclimatic (BEC) zones

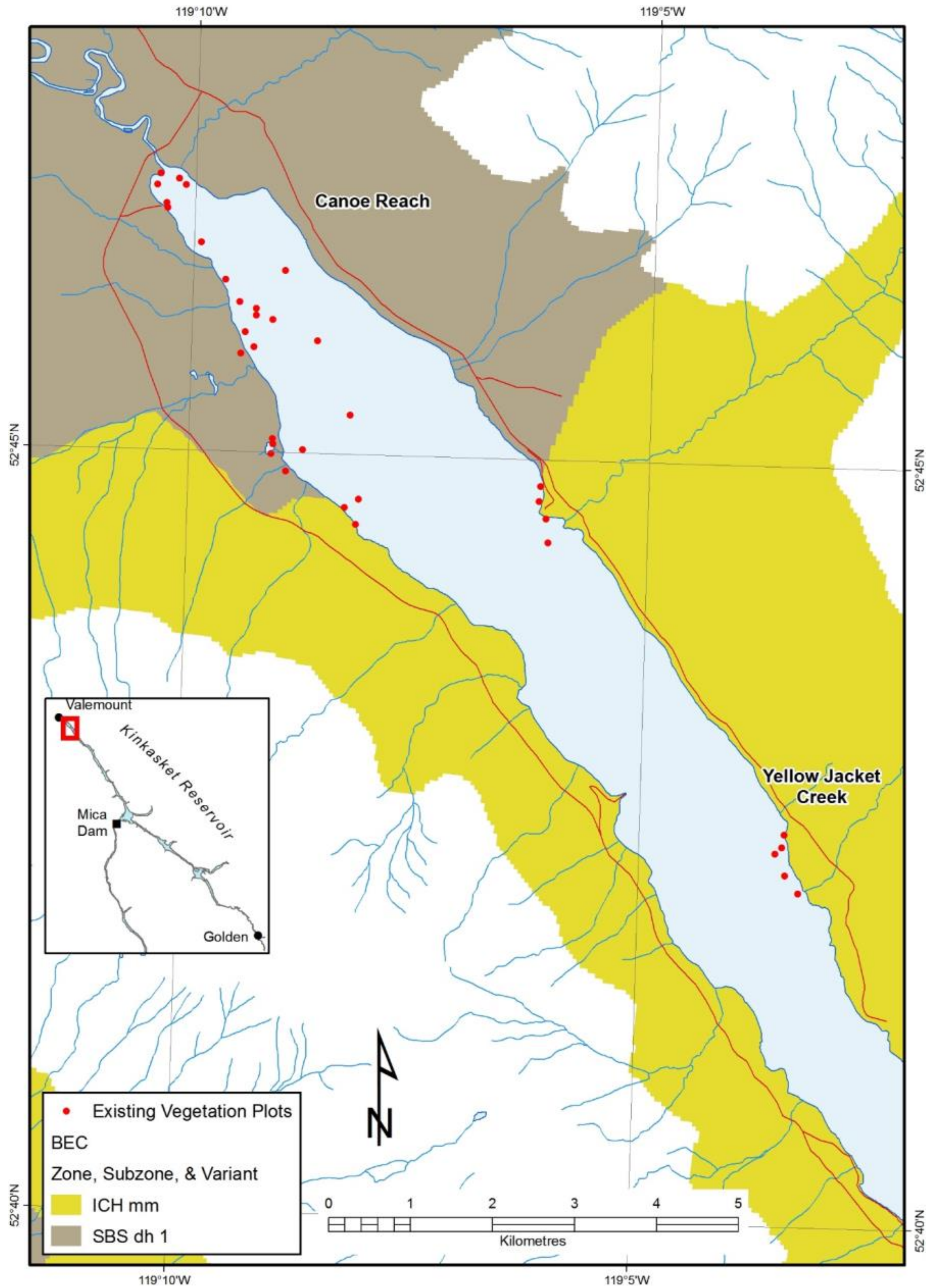

Figure 3-3: Locations of 2013 samples of existing vegetation in the north end of Kinbasket Reservoir. Refer to Table 3-1 for descriptions of biogeoclimatic (BEC) zones

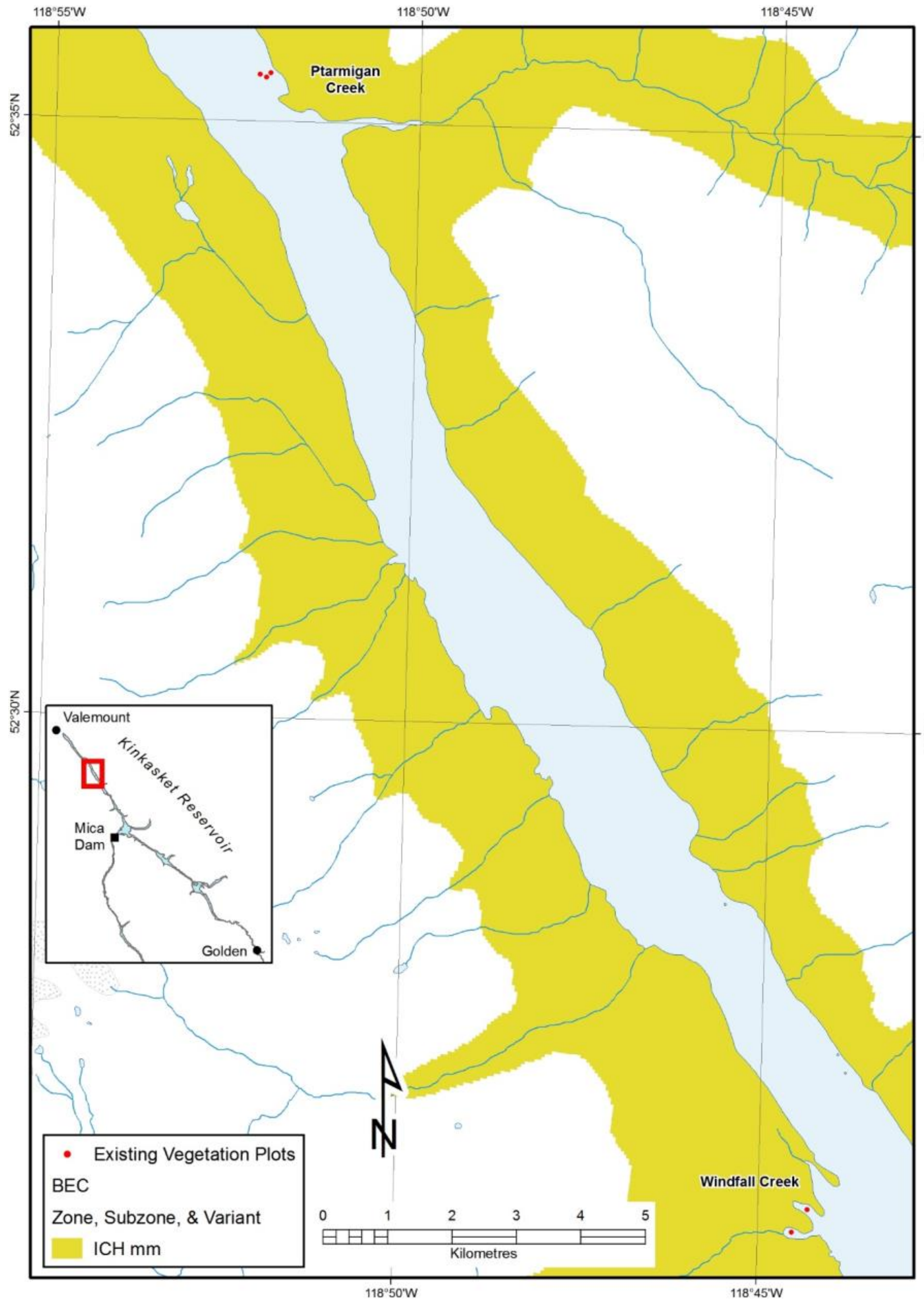

Figure 3-4: **Locations of 2013 samples of existing vegetation in the Ptarmigan Creek and Windfall Creek areas in the north portion of Kinbasket Reservoir. Refer to Table 3-1 for descriptions of biogeoclimatic (BEC) zones**

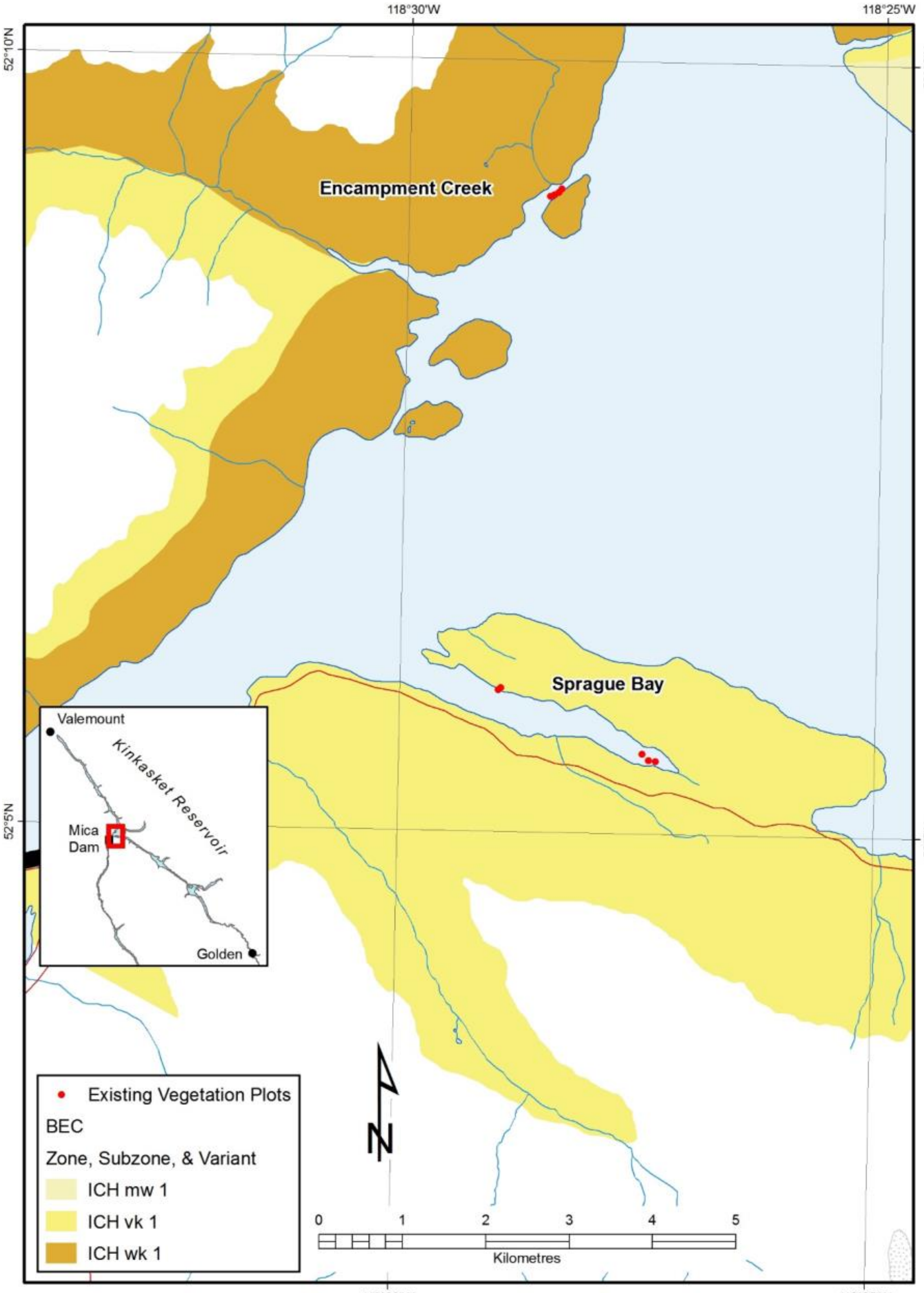

Figure 3-5: Locations of 2013 samples of existing vegetation in the Mica Creek area (central region) of Kinbasket Reservoir. Refer to Table 3-1 for descriptions of biogeoclimatic (BEC) zones

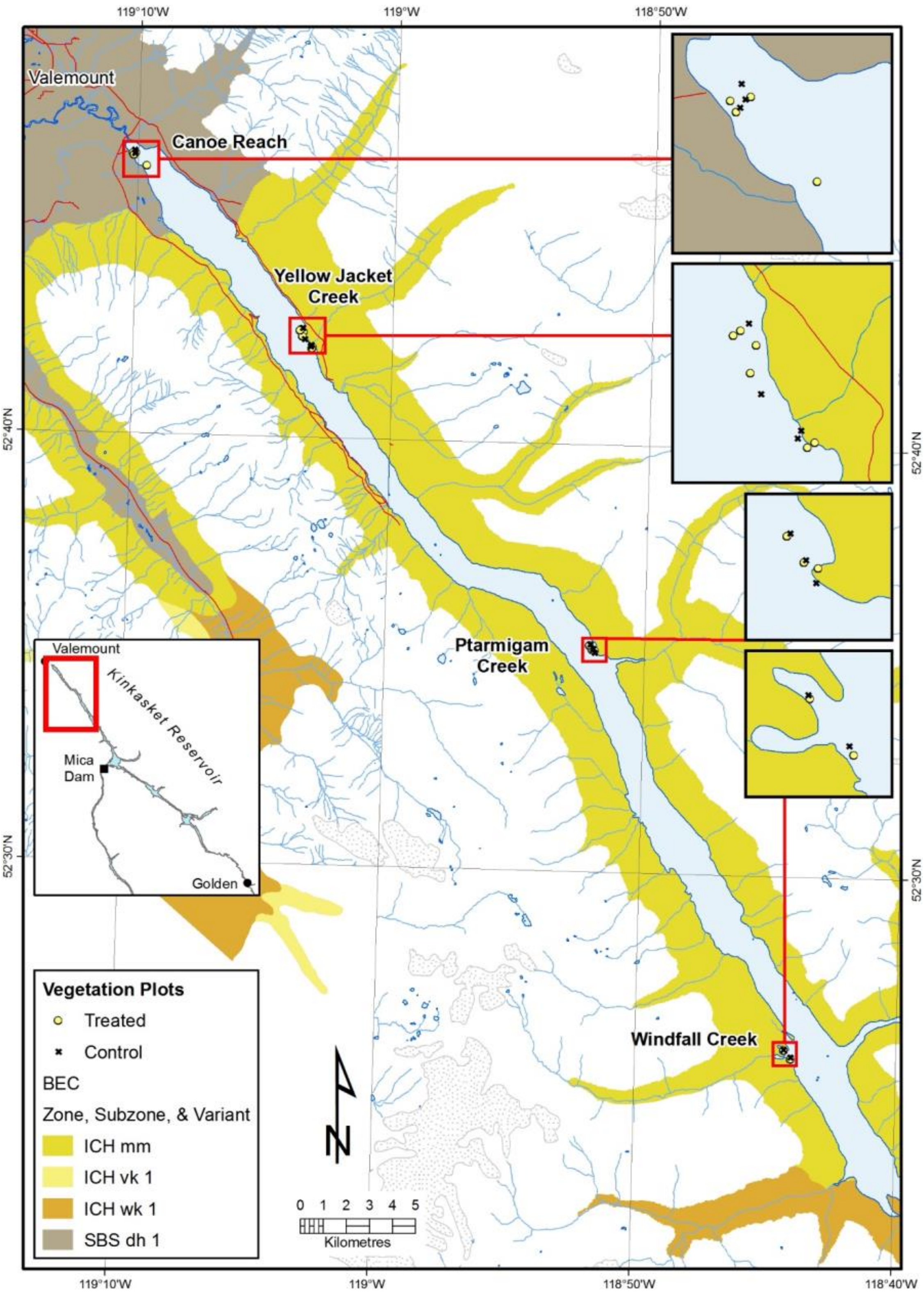

Figure 3-6: **Locations of 2013 samples of revegetated areas (treated plot: yellow circle; control plot: black "x") in the north end of Kinbasket Reservoir. Refer to Table 3-1 for descriptions of biogeoclimatic (BEC) zones**

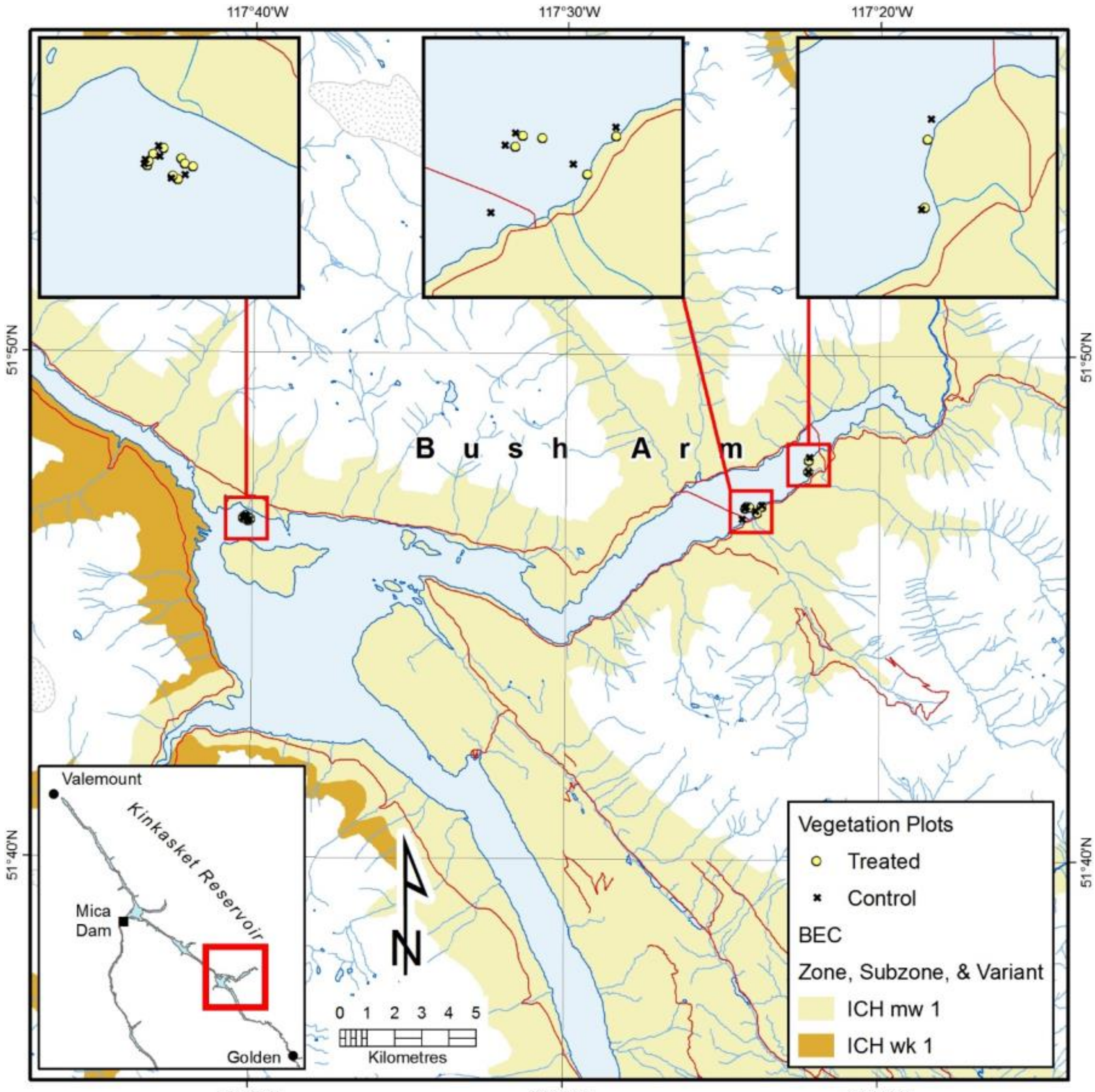

Figure 3-7: **Locations of 2013 samples of revegetated areas (treated plot: yellow circle; control plot: black "x") in the south end of Kinbasket Reservoir. Refer to Table 3-1 for descriptions of biogeoclimatic (BEC) zones**

4.0 METHODS

4.1. Study Design

The study design for the two components of the CLBMON-9 monitoring study (existing vegetation and revegetation effort) followed the methods implemented by Yazvenko (2009) and subsequently modified in Year 3 by Fenneman and Hawkes (2012). These methods are summarized below, with any changes for the Year 4 (2013) season noted where appropriate.

Sampling was stratified based on four variables:

1. **Geographic area.** Three regions of the reservoir were sampled: (1) the north (Canoe Reach), (2) central (Mica Creek area), and (3) south (Bush Arm).
2. **Vegetation communities.** Sampling was stratified among community types using the vegetation classification system developed by Hawkes et al. (2007; Table 4-1). All areas and communities sampled in 2011 were sampled again in 2013. We also added some sampling sites for existing vegetation communities that (1) were not sampled in certain strata combinations in 2011, or (2) required more sampling to better characterize the variation within the community type. Twelve of the most common community types in the drawdown zone were sampled. We also sampled in two non-vegetated habitat types (DR and NVEG) (Table 4-1).

Table 4-1: Vegetation community types identified within Kinbasket Reservoir (after Hawkes et al. 2007)

Vegetation Community Code	Vegetation Community Type	Sampled in 2013
BR	Bluejoint Reedgrass	Yes
CH	Common Horsetail	Yes
CO	Clover – Oxeye Daisy	Yes
CT	Cottonwood – Clover	Yes
KS	Kellogg's Sedge	Yes
LL	Lady's-thumb – Lamb's-quarters	Yes
MA	Marsh Cudweed – Annual Hairgrass	Yes
MC	Mixed Conifer	No
SH	Swamp Horsetail	Yes
TP	Toad Rush – Pond Water-starwort	Yes
WB	Wool-grass – Pennsylvania Buttercup	Yes
WS	Willow – Sedge	Yes
DR	Driftwood	No
WD	Woody debris	Yes
FO	Forest	No
BS	Buckbean – Slender Sedge	Yes
LH	Lodgepole Pine – Annual Hawksbeard	No
RC	Reed Canarygrass	No
CR	Common Reed	No
NVEG	Non vegetated	Yes

3. **Elevation.** We blocked elevation bands into three strata:
   - 741-745 m ASL (Low elevation zone)
   - 746-750 m ASL (Mid elevation zone)
   - 751-754 m ASL (High elevation zone)
4. **Revegetation prescription:** Between 2008 and 2011, a total of 69.15 ha of the Kinbasket Reservoir drawdown zone was planted by Keefer Ecological Services (Keefer et al. 2007, 2008, 2010, 2011; Table 4-2). Plug seedling treatments, particularly those involving Kellogg's sedge (*Carex lenticularis*) alone or mixed with other species, dominated the planting regime. Eight different revegetation prescriptions were applied during this time (ATVS = ATV seeding; BL = brush layer; EPL = excavator-planted stakes; HPL = hand-planted stakes; HPL/PS = hand-planted stakes and plug seedling; PS = plug seedling; HS = hand seeding; ST = seed trials).

   As in 2011, we restricted our assessment of revegetation effectiveness to four prescriptions that had the highest sample sizes and number of replicates:
   - hand-planted stakes (HPL)
   - hand-planted stakes and plug seedling (HPL/PS)
   - hand seeding (HS)
   - plug seedling (PS)

   Planting efforts in 2011 resulted in the smallest area being treated (8.40 ha) with the fewest treatment types (n = 6) of any of the years of the revegetation program. The largest area planted (34.76 ha) and diversity of treatment types (33) occurred during the 2009 planting season. Only Kellogg's sedge seedling treatments were conducted during each of the planting seasons; many of the other treatments were conducted only during a single year. All-terrain vehicle seeding (ATV), excavator-planted stakes (EPL) and brush layer (BL) treatments were attempted on one occasion each.

Table 4-2: Summary of revegetation efforts of the CLBWORKS-1 planting program between 2008 and 2011, including treatment types and total number of hectares treated by each specific method. ATVS = ATV seeding; BL = brush layer; EPL = excavator-planted stakes; HPL = hand-planted stakes; HPL/PS = hand-planted stakes and plug seedling; PS = plug seedling; HS = hand seeding; ST = seed trials

Treatment Type	Specific Treatment	No. Hectares Planted				
		2008	2009	2010	2011	Total
ATVS	Bluejoint machine-spread seed		0.52			0.52
BL	Brush layer		0.01			0.01
EPL	Cottonwood stakes 55 dogwood				1.10	1.10
HPL	Cottonwood live stakes		0.02			0.02
	Cottonwood/dogwood live stakes		0.06			0.06
	Willow	1.60				1.60
	Live stakes	6.28				6.28
HPL/PS	Live stakes/seeding (wetland, buffer mix)	1.38				1.38
	Hand-planted live stakes		0.37			0.37
	Hand-planted live stakes/willow seedlings		0.21			0.21
PS	Alder/willow seedling		0.56			0.56
	Black cottonwood/mountain alder			2.10		2.10
	Black cottonwood/mountain alder/willow			2.02		2.02
	Bluejoint seedling		0.19			0.19
	Bluejoint/lenticular sedge				0.96	0.96
	Columbia sedge seedling		0.20		0.12	0.31
	Deciduous seedling		1.47			1.47
	Lenticular sedge seedling	0.48	1.38	0.17	4.37	6.40
	Lenticular/Columbia sedge			1.33		1.33
	Lenticular sedge/black cottonwood/mountain alder/willow			1.41		1.41
	Lenticular sedge/woolgrass			5.86		5.86
	Lenticular/water/Columbia sedge/woolgrass			0.74		0.74
	Lenticular sedge/woolgrass/water sedge seedling				1.27	1.27
	Mixed hardwood seedling		0.72			0.72
	Mixed plugs	0.02				0.02
	Mixed plugs (willow/cottonwood/rose)	0.00				0.00
	Mixed plugs (willow/cottonwood/rose/lenticular sedge)	0.06				0.06
	Mixed species seedling		15.06			15.06
	Mixed wetland seedling		0.20			0.20
	Small-fruited bulrush seedling	0.07	0.57	0.14		0.78
	Small-fruited bulrush/water sedge seedling		0.13			0.13
	Water sedge seedling		0.10	0.41		0.51
	Water sedge/lenticular sedge/woolgrass/small-fruited bulrush			0.66		0.66
	Water sedge/small-fruited bulrush seedling		0.35			0.35
	Water sedge/woolgrass seedling		0.03			0.03
	Wetland seedling		0.09			0.09
	Willow seedling				0.59	0.59

Treatment Type	Specific Treatment	No. Hectares Planted 2008	2009	2010	2011	Total
	Willow/bluejoint reedgrass	0.17				0.17
	Woolgrass seedling	0.08	0.21	0.11		0.40
	Woolgrass/Columbia sedge/small-fruited bulrush seedling		0.01			0.01
HS	BC Hydro upland mix hand seeded area		0.29			0.29
	BC Hydro wetland seed mix		0.94			0.94
	Bluejoint hand seeded area		0.08			0.08
	Bluejoint mixed seed		1.47			1.47
	Bluejoint seed		2.68			2.68
ST	BC Hydro upland/BC Hydro wetland seed mix		0.07			0.07
	BC Hydro upland/wetland mix, lenticular sedge		3.06			3.06
	BC Hydro wetland seed mix		0.54			0.54
	Lenticular sedge coated seed		1.55			1.55
	Lenticular sedge pellet seed		0.24			0.24
	Lenticular sedge seed	0.14	1.37			1.51
	Upland seed mix	0.73				0.73
	Total no. hectares ATVS		**0.52**			**0.52**
	Total no. hectares BL		**0.01**			**0.01**
	Total no. hectares EPL				**1.10**	**1.10**
	Total no. hectares HPL	**7.88**	**0.08**			**7.96**
	Total no. hectares HPL/PS	**1.38**	**0.59**			**1.97**
	Total no. hectares PS	**0.88**	**21.28**	**14.97**	**7.30**	**44.43**
	Total no. hectares HS		**5.46**			**5.46**
	Total no. hectares ST	**0.87**	**6.83**			**7.70**
	TOTAL NO. HECTARES PLANTED	**11.01**	**34.77**	**14.97**	**8.40**	**69.15**

4.1.1. Mapping

Updated vegetation community maps developed for the 2012 sampling year for CLBMON-10 (Hawkes et al. 2013) were used to select sampling sites for CLBMON-9.

4.1.2. Treatment and Control Sites

For revegetation treatments, efforts were made to sample all strata combinations (community x elevation x planting prescription) occurring in each region of the reservoir. However, not all combinations of strata exist in all geographic regions, due mainly to the differential distribution of vegetation communities in the drawdown zone. All revegetation sample sites (treatment and control) were ones that had been previously established, i.e., no new sites were established for 2013. Some were sites established 2008 or 2009, but most were established in 2011. This is because the sampling design in 2008 and 2009 did not treat revegetation treatment type as a separate stratum. Consequently, some combinations of treatment type, elevation, and vegetation community type were not adequately represented in the earlier sampling.

Revegetation treatments were applied in 2008 (Bush Arm), 2009 (Canoe Reach), 2010 (Bush Arm) and 2011 (Bush Arm). In 2008 only Bush Arm (i.e., the south) was sampled, and in 2009 only the north (i.e., Canoe Reach) was sampled. In 2011, sites were established in both north and south.

The 2013 plots were determined in the office prior to field work. Using GIS, the distribution of 2008, 2009, 2010, and 2011 revegetation treatment polygons were projected, as were the 2010 vegetation community polygons. Elevations were projected using the Kinbasket digital elevation model. For every combination of elevation, vegetation community, and treatment type that occurred in the north and south ends of Kinbasket Reservoir, we selected a plot for both a treatment (revegetation treatment) and untreated control to derive a series of paired (treatment and control) samples.

Controls were established in 10 x 20 m sites that were selected in two ways: (a) by the CLBWORKS-1 team within areas subjected to treatments and (b) within the control (reserved) polygons in areas as similar as possible to treatment areas (in terms of vegetation community and elevation). Controls sites were selected to represent vegetation that was similar to that being treated, but were left untreated for the duration of the study and were presumed to not be influenced by seed contamination from adjacent treated areas.

During the life of the project, some sample sites may become inaccessible through changes in the reservoir's physical conditions or changes in access. However, this is not deemed to be a serious issue, and there are sufficient sites in the various strata of the design to absorb up to a 10 per cent loss of sites without affecting incommensurably the statistical power of the tests. Barring a physical disappearance of a site, any changes that occur, including such drastic changes as the results of debris removal, will be deemed part of the habitat dynamics within the drawdown zone of the reservoir, and resampling of such sites will continue.

The location of plots was non-random. Rather, the aim was to purposely select locations in the north and south ends of Kinbasket Reservoir that were representative of the various combination of elevation, revegetation prescription and vegetation community. Because this is an effectiveness monitoring study, we felt it more important to purposely sample within each combination (as opposed to randomly selecting locations to sample) so that we could assess the overall effectiveness of the revegetation program. The permanent plots established in 2011 can be resampled in the future to derive a time series dataset for the existing vegetation and revegetation polygons.

4.1.2.1. Field Sampling

Once on the ground, a researcher stood at the predetermined plot centre (marked with a capped rebar stake at the time of establishment) and made three random tosses of a 0.71 m x 0.71 m (0.5 m^2) quadrat frame. This is a standard technique for describing non-forest vegetation (Mueller-Dombois and Ellenberg 1974; Bonham 1989).

Vegetation within each quadrat was identified to species, or in some cases, to genus, and the percentage cover was visually estimated following Mueller-Dombois and Ellenberg (1974). Plant nomenclature followed Douglas et al. (1998a, 1998b, 1999a, 1999b, 2000, 2001a, 2001b, 2002) with current amendments. Stand structure data were collected based on a modification of the

FS882 (3) Vegetation Form (Luttmerding et al. 1998). Vegetation was listed by layer:

A1: Dominant trees
A2: Main canopy trees
A3: Sub-canopy trees
B1: Tall Shrubs (woody plants 2 m to 10 m tall)
B2: Low Shrubs (woody plants less than 2 m high)
C: Herbs (forbs and graminoids)
D: Moss, lichen, seedlings and substrate surface

Total species cover was visually estimated for each quadrat, and a mean per cent cover per quadrat was computed in office.

Vegetation vigour was assessed using a qualitative scale of good, moderate, and poor. Good was defined as the majority of plants (> 75 per cent) surviving and having an outward appearance of good health (no brown leaves, healthy looking plants). Moderate was defined as most plants (between 50 and 75 per cent) surviving and mostly healthy (some yellowing or wilting). Low was defined as poor survivorship (< 50 per cent) and obvious signs of poor health (brown levels, more than 50 per cent of each plant was wilted or yellowed, dead or dying plants). Vigour was assessed along with plant survivorship.

4.1.2.2. Survivorship and Vigour

The survivorship of plants used in the revegetation program was assessed in three 5 x 5 m subplots centred on the 0.5 m^2 quadrat. Only revegetated areas were assessed for survivorship. The subplots were positioned to represent the overall condition of the plants in each site. Within these subplots, the total number of seedlings or stakes that were observable was recorded, as well as the number of these individuals that were dead and the number that were alive. This enabled a direct assessment of the survivorship of the planting treatments by comparing the number of plants that had survived since planting and the number that had died.

The overall vigour of the plants in the plot was assessed using a qualitative scale, of good, moderate, and poor. “Good” was defined as the majority of plants (> 75 per cent) surviving and having an outward appearance of good health (no brown leaves, healthy looking individuals). “Moderate” was defined as most plants (between 50 and 75 per cent) surviving and mostly healthy (some yellowing or wilting). “Low” was defined as poor survivorship (< 50 per cent) and obvious signs of poor health (brown leaves, > 50 per cent of each plant wilted or yellowed, or dead or dying plants).

4.1.2.3. Soil Sampling

Soils were sampled to investigate how they varied in their capacity to support vegetation and whether there was a relationship between the duration, depth and timing of inundation and the texture and chemical parameters of soils. A combined soil sample was obtained by sampling the upper 20 cm of the substrate within a given sample site (but not within a quadrat) in each combination of vegetation community type, elevation, revegetation prescription and geographic area. Samples were obtained for both treatment and control sites but not for existing vegetation sites. A subsample of each soil sample (enough to fill a medium-sized Ziploc bag) was collected using a small spade. These soil samples were stored in a cooler during the field session and were immediately shipped away for analysis following the completion of each field session.

Laboratory analyses of the soil samples collected from treated and control sites were conducted by the Laboratory Services Division, University of Guelph (ON),[7] and included determination of the following parameters:

- organic matter
- total carbon (C)
- inorganic carbon
- organic carbon
- total nitrogen (N)
- phosphorus (P)
- potassium (K)
- magnesium (Mg)
- calcium (Ca)

4.1.2.4. Vegetation Biomass and Nutrient Analysis

Vegetation samples were collected at each treatment and control site for analysis of nutrient content. Within each of the three quadrats at each of these sites, a 0.5 x 0.5 m subplot was installed, within which all aboveground vegetation matter was clipped and collected. The clipped vegetation was allowed to dry inside paper bags while in the field and was shipped away for analysis following the completion of each field session. Laboratory analyses of the biomass samples were conducted by the Laboratory Services Division, University of Guelph (ON),[8] and included determination of the following parameters:

- sample total weight
- inorganic carbon (per cent)
- organic carbon (per cent)
- total nitrogen (per cent)
- sample weight dry ash (P, K, Mg, Ca)
- phosphorus (per cent)
- potassium (per cent)
- magnesium (per cent)
- calcium (per cent)

Biomass samples were weighed to the nearest 0.01 g using standard methods (USDA-NRCS 1997). Other analyses were conducted following LECO instruction/operations manual for the FP428 Nitrogen and Protein Determinator, Version 2.4 (www.leco.com), as follows:

Carbon

The LECO SC444 was used to measure the total C and/or sulphur content in soil, plant, waste and other samples. Inorganic C was determined by ashing the sample at 500°C for three hours prior to LECO SC444 use. Organic C content was calculated by subtracting the inorganic C result from the total C result. The

[7] This unit is not associated with LGL Limited.
[8] This unit is not associated with LGL Limited.

LECO SC444 method of C determination is based on the combustion and oxidation of C to form carbon dioxide (CO_2) by burning the sample at 1350°C in a stream of purified oxygen. The amount of evolved CO_2 was measured by infrared detection and used to calculate the percentage of C in the sample.

LECO Nitrogen

This method, based on the Dumas Method, is routinely used to analyze total N in plant and soil samples. Samples were dried and ground or sieved prior to analysis. The samples were combusted in a sealed system. Nitrogen compounds released were reduced to nitrogen dioxide gas, which was measured by a thermal conductivity cell using the LECO FP428.

Phosphorus, Potassium and Dry Ash

This method, described by Western States Laboratory Proficiency Testing Program (1997), quantitatively determines the concentration of P and K in plant materials using a high temperature dry oxidation of the organic matter and the dissolution of the ash with 1M hydrochloric acid. Digest analyte concentrations were determined using Varian ICP-OES.

4.2. Statistical Analyses

4.2.1. General Community Descriptors

The per cent cover of all vegetation species recorded in each quadrat was averaged to derive an estimate of total cover overall and per species for each site. Trends among vegetation communities, regions, type of treatments, and elevation bands were mostly on two years of data (i.e., 2011 and 2013).

Total cover, species richness, and species diversity were assessed over time by geographic area, elevation, vegetation community, and revegetation prescription. Species richness was defined as the number of species occurring in the sites of each combination of strata. Diversity was computed as Shannon's index and corresponded to a measure of species composition, combining both the number of species and their relative abundances (Legendre and Legendre 1998).

Total cover, richness, and diversity of vegetation according to geographic location, revegetation prescription, vegetation communities and elevation were summarized through box sites (Massart et al. 2005). Box plots display the differences between groups of data without making any assumptions about their underlying statistical distributions and show their dispersion and skewness (Massart et al. 2005). Boxes represent between 25 per cent and 75 per cent of the ranked data. The horizontal line inside the box is the median. The length of the boxes is their interquartile range (Sokal and Rohlf 1995). A small box indicates that most data are found around the median (small dispersion of the data). The opposite is true for a long box: the data are dispersed and not concentrated around the median. Whiskers are drawn from the top of the box to the largest observation within 1.5 interquartile range of the top, and from the bottom of the box to the smallest observation within 1.5 interquantile range of the bottom of the box.

Differences in total cover, species richness, and diversity between years and among vegetation communities, landscape units or elevation bands were tested with a series of two-way unbalanced analyses of variance (ANOVAs). ANOVAs were performed in the R language (Version 2.15.2) and the F-distribution was tested with 99,999 permutations.

4.2.2. Vegetation Species Associations

Vegetation species associations were investigated with the Kendall Coefficient of concordance, K-Means partitioning, and canonical ordination (Legendre 2005; Legendre and Legendre 1998). These are techniques used to find and group species sharing similar associations with environmental characteristics; here the objective was to determine if patterns of species clustering could be used to expose differences between the control and treated vegetation.

Community composition data, such as cover values, frequently contain a high frequency of zeros which produce highly positively skewed frequency distributions of the species abundances across sites (Legendre 2005). A transformation of the data is necessary to make them suitable for statistical analyses through Principal Component Analysis or canonical analyses, which preserves Euclidian distances (Legendre and Gallagher 2001). The Hellinger distance transformation was hence applied to all cover values of species. It corresponds to taking the square root of the proportion of each species at a site (Legendre and Gallagher 2001). It thus applies well to cover data, as cover data are proportions.

An overall test of independence of all species in the study was then conducted. If such a test is found significant, it suggests that certain species are concordant in their estimation of common properties of sites (Legendre 2005). The next step taken was to group the species with K-Means partitioning and test with permutations, within each group, the contribution of each species to the overall statistic. That allowed determining which of the individual species were concordant with one or several of the other species (Legendre 2005). The null hypothesis is then that of monotonic independence of the species subjected to the test; the alternative hypothesis is that the species is concordant with other species in the study. In order to preserve an approximately correct experiment wise error rate, the probabilities of the tests were adjusted for multiple testing (Legendre 2005). The correction of Holm (1979) recommended for sets of non-independent tests by Wright (1992) was used. The W coefficient was tested with 100,000 permutations. The results of the groupings were then plotted on a PCA diagram. All analyses were performed in the R language (Version 2.15.2).

5.0 RESULTS

5.1. Field Sampling

Field sampling was conducted over two field sessions: June 16–29, 2013 and July 15–22, 2013. The dates for the 2013 field sessions were similar to those in 2008, 2009, and 2013 (Yazvenko 2009; Yazvenko et al. 2010). Reservoir elevations ranged from 736 to 742 m ASL during the first field session and from 749 to 751 m ASL during the second field session (Figure 5-1). Field sampling was conducted during periods when all elevation strata were available for sampling.

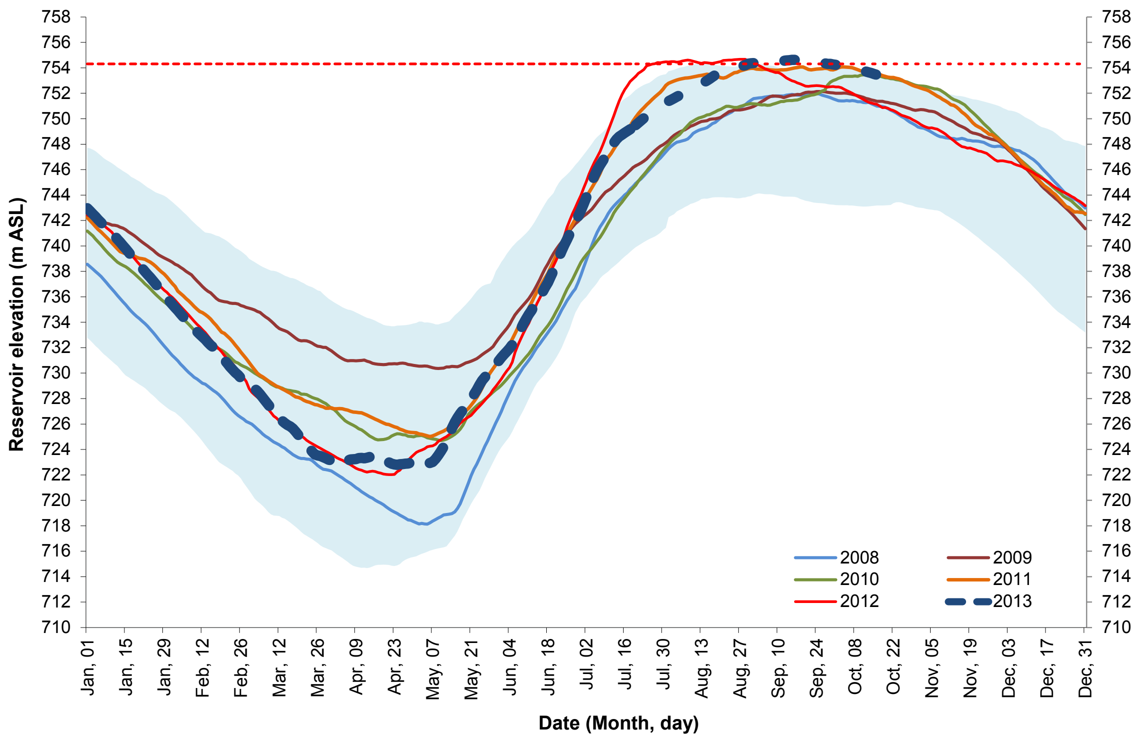

Figure 5-1: Kinbasket Reservoir hydrograph for the period 2008 through 2013. The shaded area represents the 10th and 90th percentile for the period 1976 to 2013; the dashed red line is the normal operating maximum

5.2. Existing Vegetation

5.2.1. Sampling Effort

Existing vegetation communities were resampled through the north, central, and southern reaches of Kinbasket Reservoir (Table 5-1). Most resampling was conducted in the north and south to align with work completed from 2008 to 2011. Some resampling was also conducted in the vicinity of Mica Dam (i.e., the central region). The number of sites and vegetation communities resampled in each geographic strata varied relative to the distribution of, and access to, the various vegetation communities delineated for those regions. A total of 14 communities (12 vegetated, two non-vegetated) were resampled across three elevation bands: eight in the north region, four in the central, and 11 in the south region.

Table 5-1: Number of sites and vegetation communities (VC) sampled in existing vegetation per elevation and geographic strata in the drawdown zone of Kinbasket Reservoir in 2011 / 2013

	741–745 m ASL			746–750 m ASL			751–754 m ASL		
VC Code[a]	**North**	**Central**	**South**	**North**	**Central**	**South**	**North**	**Central**	**South**
BR	--	--	--	--	--	2 / 2	2 / 3	--	-- / 1
BS	--	--	--	--	--	--	2 / 2	--	--
CH	1 /1	--	1 / 3	5 / 6	--	4 / 3	1 / 1		2 / 1
CO	--	--	--	--	--	--	4 / 3	1 / 1	4 / 4
CT	--	--	--	--	--	--	--	--	2 / 1
DR	--	--	--	--	--	--	--	--	-- / 1
KS	2 / 2	-- / 1	4 / 4	-- / 1	4 / 1	5 / 7	2 / 2	--	--
LL	5 / 4	--	8 / 6	1 / 1	--	2 / 2	1 / 1	--	--
MA	--	--	2 / 2	--	--	4 / 2	--	--	--
SH	--	--	--	-- / 2	--	1 / 3	-- / 1	--	5 / 5
TP	2 / 2	1 / 1	5 / 2	1 / 2	--	1 / 1	--	--	--
WB	-- / --	1 / 1	--	-- / --	2 / 4	3 / 3	2 / 2	--	--
WD	1 / 1	--	--	1 / 2	--	--	--	--	--
WS	--	--	--	--	--	--	3 / 2	--	4 / 4
No. sites	**11 / 10**	**2 / 3**	**20 / 17**	**8 / 14**	**6 / 5**	**22 / 23**	**17 / 17**	**1 / 1**	**17 / 17**
No. communities	**5 / 5**	**2 / 3**	**5 / 5**	**4 / 6**	**2 / 2**	**8 / 8**	**8 / 9**	**1 / 1**	**5 / 7**

[a] See Table 4-1 for definitions of VC codes.

Of the total sites sampled for existing vegetation in 2013 (107), 40 sites were located in the north (Canoe Reach), nine were located in the central reach (Mica Creek) and 58 sites were in the south (Figure 3-2, Figure 3-3, Figure 3-4, Figure 3-5, Appendix 9-C).

5.3. Revegetation Effectiveness

5.3.1. Survivorship and Vigour

The survivorship of plug seedlings has declined rapidly in the years following planting. By 2011, < 40 per cent of plugs planted in 2009 were recorded as still surviving (Fenneman and Hawkes 2012). In the two years subsequent, plug survivorship has continued to decline. By 2013, the most recent year of sampling, few of the polygons that received plug seedlings in 2009 still contained live plugs (one out of six sites in our sample). Individual survivorship rates were difficult to derive for 5 x 5 m sample plots because only the surviving plugs were visible; plugs that had died in previous years had either rotted or floated away, making it impossible to determine precisely how many plugs were in the ground originally (N_0). Instead, we assumed an N_0 of ~58 plugs per 25 m^2 plot based on the average planting densities reported by Keefer et al. (2011). Using this extrapolation, the average survivorship of plugs four years after planting (t = 4) was 4 per cent. For plugs planted in 2010 and 2011 (t = 3 and t = 2), survivorship was 7 per cent and 44 per cent, respectively (Figure 5-2). Two of the polygons sampled were planted with plugs twice: first in 2010 and again in 2011. In those polygons, only three per cent of planted plugs were still surviving in 2013.

The vigour of surviving plug seedlings also declined steadily with time since planting. The percentage of revegetation sites assessed as having overall "good" or "moderate" vigour dropped from 75 per cent for sites that were planted in 2011 to 8 per cent for sites that were planted in 2010 and 14 per cent for sites that were planted in 2009. Similarly, the number of sites assessed as exhibiting "poor" vigour increased from 25 per cent for 2011 sites to 92 per cent for 2010 sites to 86 per cent for 2009 sites. The slightly better results for 2009 plugs versus 2010 plugs in our sample was due entirely to successful establishment of plugs within one polygon at Yellow Jacket Creek (north reservoir region). As might be expected, the sites with higher survivorship also tended to have better vigour ratings (Figure 5-3).

The survivorship of live stakes planted in 2008 was assessed at two different treatment sites, but mortality at each of these sites was 100 per cent (one site did have a single surviving willow plant though it was unclear if this was hand-planted or natural). Two sites treated (in 2009) with a combination of live stakes and sedge plugs (HPL/PS) also had 100 per cent mortality.

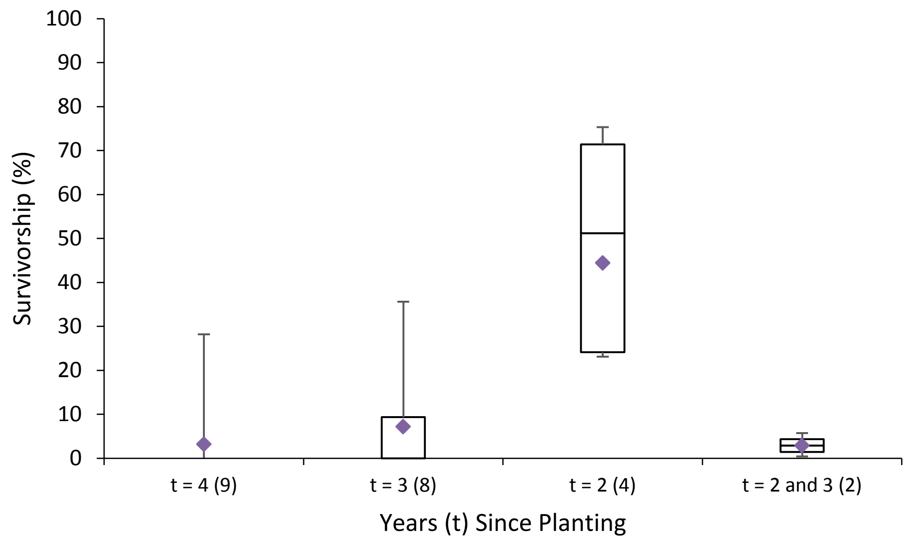

Figure 5-2: Survivorship in 2013 of plug seedlings (PS) planted in 2009, 2010, and 2011 (t = 4, t = 3, t = 2), and in plots treated first in 2010 and again in 2011 (t = 2 and 3). Purple diamonds indicate average survivorship. Numbers in parentheses are the sample size for that year.

The trends in both live deciduous stake and sedge plug seedling survivorship suggest that there is considerable mortality and loss of vigour during the years following revegetation of the drawdown zone, with mortality exceeding 95 per cent after four years of planting. The mortality of stakes and plugs can probably be attributed to a combination of natural attrition, human-caused habitat alteration (e.g., woody debris removal), prolonged inundation, erosion, and heavy sedimentation. Because abiotic pressures are unlikely to abate in the near future, continuing declines in transplant survivorship can be expected. Nevertheless, this remains to be seen. It is possible that the transplants that have successfully persisted until now are naturally more robust and hence better equipped to deal with prevailing reservoir conditions, in which case we could see stabilizing numbers and a leveling out of the mortality curve.

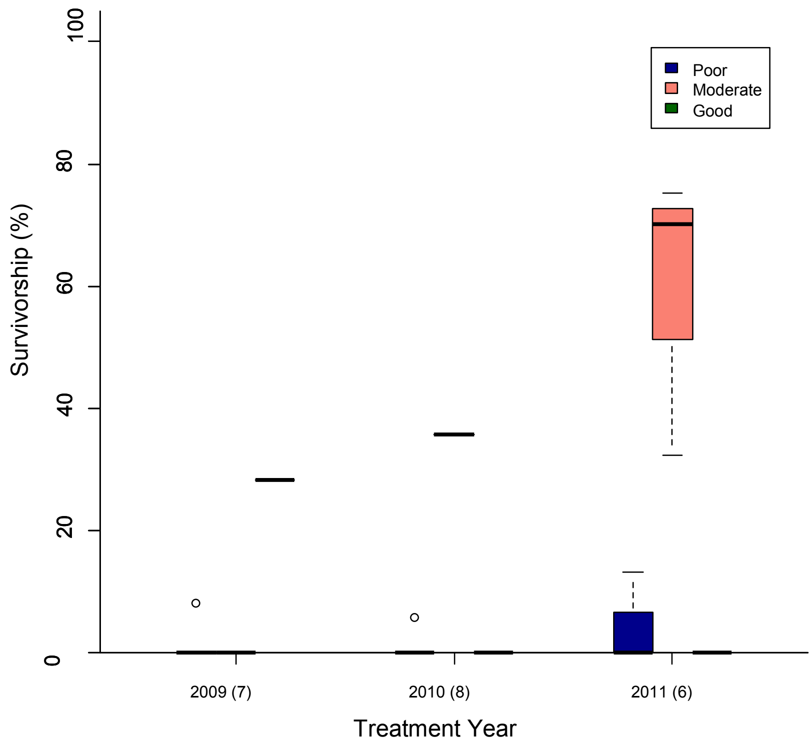

Figure 5-3: Survivorship of plug seedlings (PS) in sites attaining different "vigour" ratings, for sites treated in 2009, 2010, and 2011. Different coloured boxes represent different vigour ratings (poor, moderate, good). Survivorship was averaged over three 25 m^2 plots per site, and vigour was attributed to each site based on the most frequent rating over the three plots. Vigour ratings were based on a visual estimate of the overall health of the transplants (number in parentheses is the sample size for that year)

5.3.2. Per Cent Cover

We recorded generally low vegetation covers in our samples (Figure 5-4). Per cent cover was higher in existing vegetation sites than in either control or treated sites. Only existing and control sites in the south region appeared to increase in cover (slightly) between 2011 and 2013 (Figure 5-4). Differences in cover were statistically significant among the types of site both in the north (F = 8.7, p = 0.0004) and in the south (F = 18.7, p = 0.00001) of the reservoir, likely because of the higher cover in existing sites (central region not tested). Differences between years were not statistically significant.

Similarly, there were no statistically significant differences in per cent cover of vegetation in treatment versus control sites when sites were stratified by vegetation community type (Figure 5-5). Cover within different community types changed little between 2011 and 2013. Cover increased slightly in treated sites in the CO and SH community and decreased slightly in control sites, while this trend was reversed for the CT community. However, these differences were not significant. Differences among control, treated, and existing sites in 2013 were significant only for the MA community (one-way ANOVA, F = 10.3, p = 0.007), which can likely be ascribed to the relatively higher cover within existing sites.

There was also little difference between control and treated sites after stratifying by elevation (Figure 5-6). All site types (control, existing, and treated) showed a marginal increase in cover between 2011 and 2013 at the lowest elevation band (mainly reflecting higher variances in cover values as opposed to higher median values), were generally unchanged at the mid elevation band, and decreased slightly at the higher elevations. This latter result may reflect the impacts of the full pool event in 2012, as these events tend to affect vegetation at the upper drawdown zone elevations the most (Hawkes et al. 2013). Differences in cover were significant among types of site at high and middle elevation only ($F = 12.1$, $p = 0.00007$; and $F = 31$, $p = 0.00001$, respectively), again reflecting the higher cover within existing sites. Differences between years were not statistically significant.

Cover declined for most planting prescriptions between 2011 and 2013, in both control and treated sites, and particularly for HPL/PS treatments (Figure 5-7). Only hand seeded sites (HS) seem to have shown an increase relative to control sites since 2011, although it is difficult to assign this difference to treatment effects since we observed little evidence of successful establishment from seed mixes. In the one prescription that has experienced some survivorship success, plug seedling (PS), cover increased marginally in control sites but remained stable in treated sites. No differences in cover among types of sites or treatment prescriptions were statistically significant, for either year.

The overall higher cover values for existing vegetation sites, while notable, are likely just an artifact of the study design. During the original site selection process for CLBWORKS-1, barren areas (rather than already vegetated areas) were often selectively chosen to receive treatments. Since the control sites are physically adjacent to the treated sites, they also tended to be more barren at the outset than the more random selection of existing vegetation sites. Absolute cover (and species richness/diversity) values notwithstanding, the primary purpose for including existing sites in the comparison is to indicate whether the directional changes from year to year (if such exist) apply to the habitat generally, or if they are specific to the treatment areas.

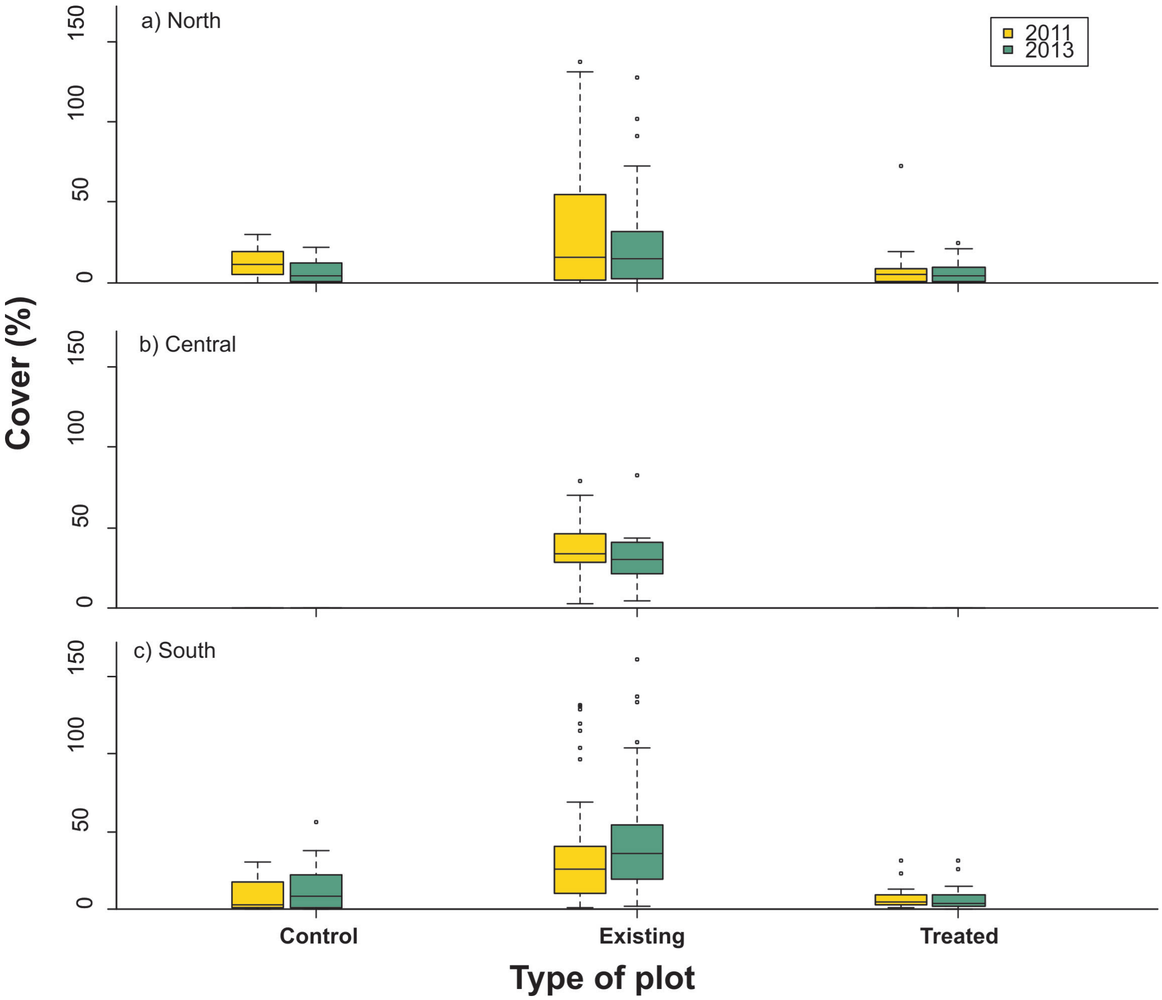

Figure 5-4: **Per cent cover of vegetation in control, existing, and treated sites across different regions (north, central, south) of Kinbasket Reservoir in 2011 and 2013. "Existing" sites are areas of natural vegetation occurring within the same strata as, but not directly associated with, the revegetation trials**

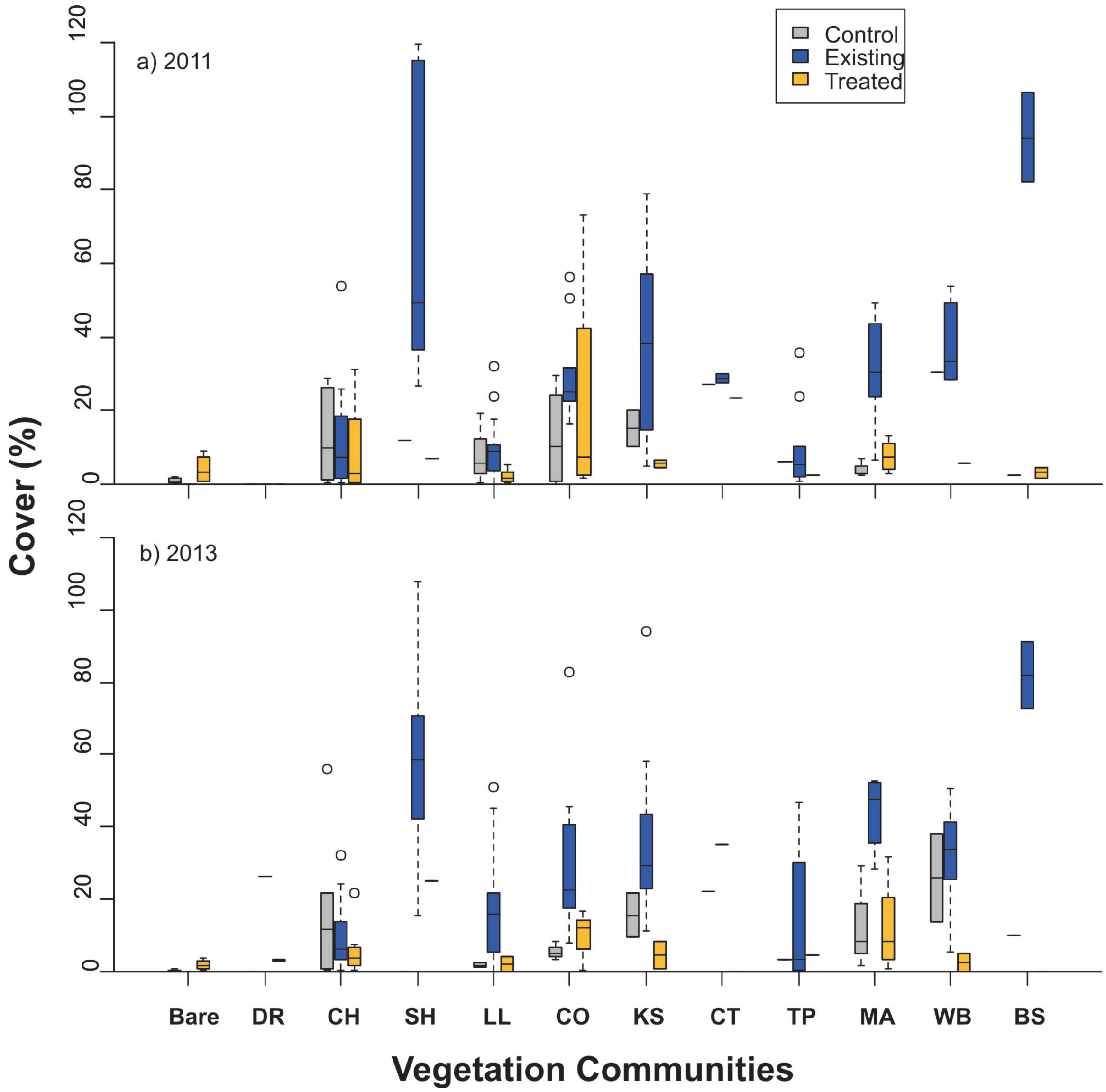

Figure 5-5: **Per cent cover of vegetation in control, existing, and treated sites across different vegetation communities sampled in 2011 (upper) and 2013 (lower). See Table 4-1 for vegetation community codes. "Existing" sites are areas of natural vegetation occurring within the same strata as, but not directly associated with, the revegetation trials**

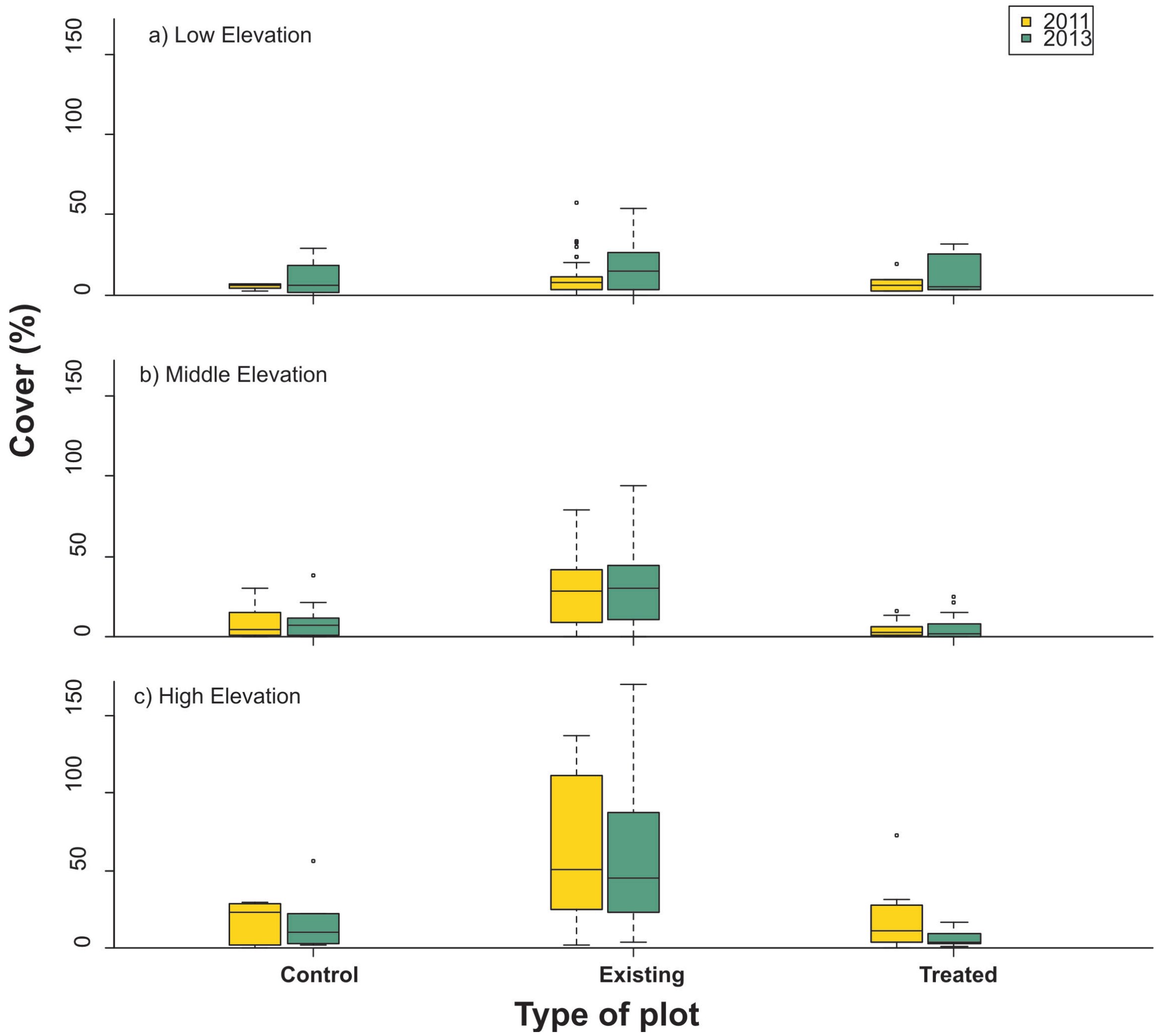

Figure 5-6: **Per cent cover of vegetation in control, existing, and treated sites across elevation bands within the drawdown zone of Kinbasket Reservoir in 2011 and 2013. Low = 741–745 m ASL; Mid = 746–750 m ASL; High = 751–754 m ASL. Note different scales on y-axis for different elevation bands. "Existing" sites are areas of natural vegetation occurring within the same strata as, but not directly associated with, the revegetation trials**

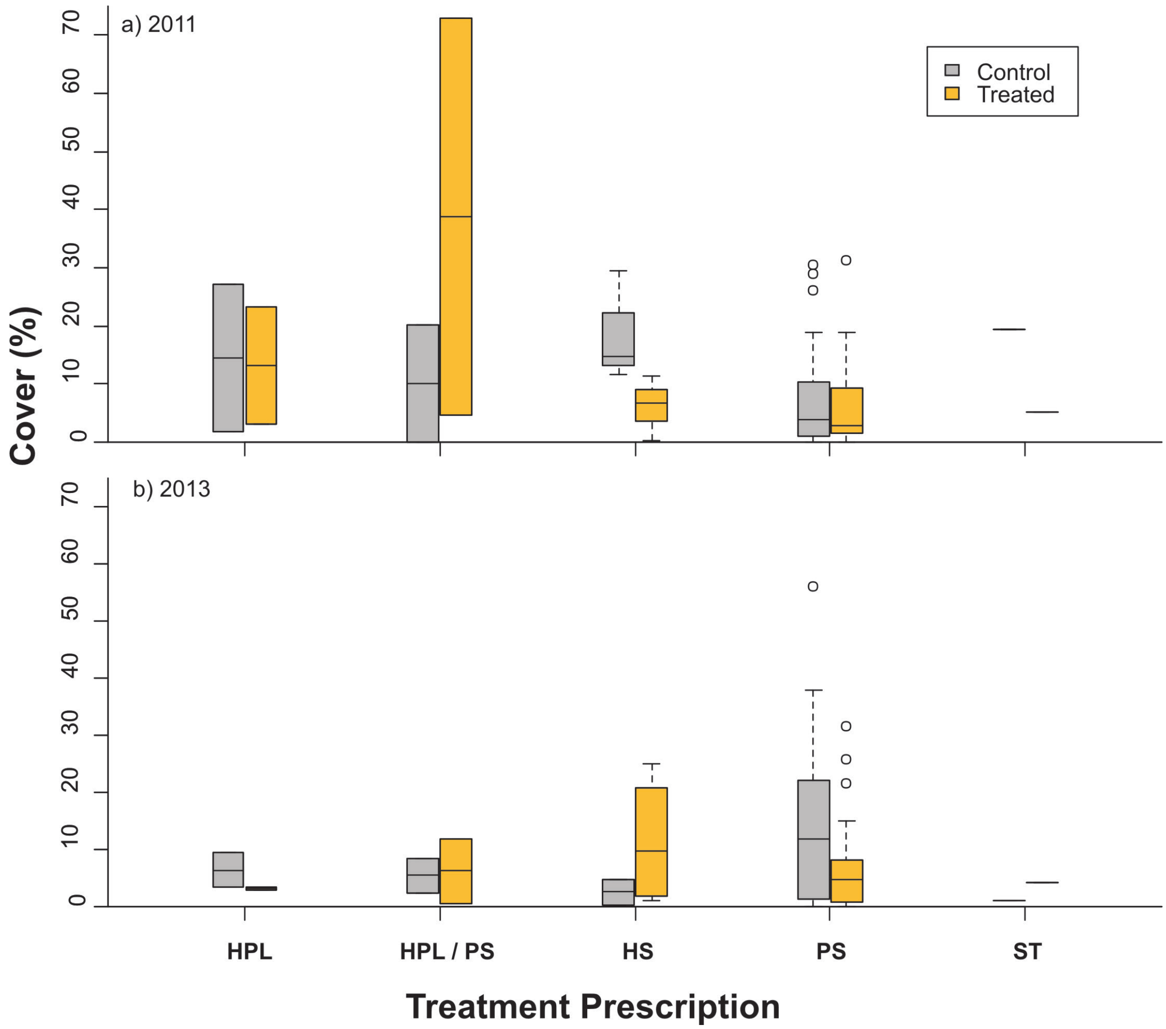

Figure 5-7: Per cent cover of vegetation for different treatment types in 2011 (upper) and 2013 (lower). See Table 4-2 for treatment codes

5.3.3. Species Richness

In contrast to per cent cover, species richness declined for all three elevation bands (Figure 5-8). There was a comparable decline in richness between treated and control sites at low and mid elevations, but treated site richness appeared to decline more than control site richness at high elevation (Figure 5-8). Differences in species richness were statistically significant among years and types of site at middle elevation (F = 8.7, p = 0.004 and F = 6.8, p = 0.0015, respectively), and between years at low elevation (F = 23.75, p = 0.00001; interactions, F = 3.15, p = 0.048). There were significant differences in species richness between 2011 and 2013 for control (F = 6.5, p = 0.03), treated (F = 9.8, p = 0.02), and existing sites (F = 8.9, p = 0.0035), but not among types of site in 2011 or 2013 (p > 0.05).

Stratifying sites by planting prescription, there was a ~50 per cent decline in species richness for both control and treated sites between 2011 and 2013 (Figure 5-9). Declines were most pronounced for the treated plots and were particularly evident for plots treated with HPL and HPL/PS. There was an increase in species richness in plots treated with ST, but only one plot was sampled for that treatment. Differences in species richness were not statistically significant among types of plot or treatment prescriptions ($p > 0.05$). These results indicate that species richness declined significantly between 2011 and 2013 in all types of sites and that revegetated sites have fared no better or worse in this regard.

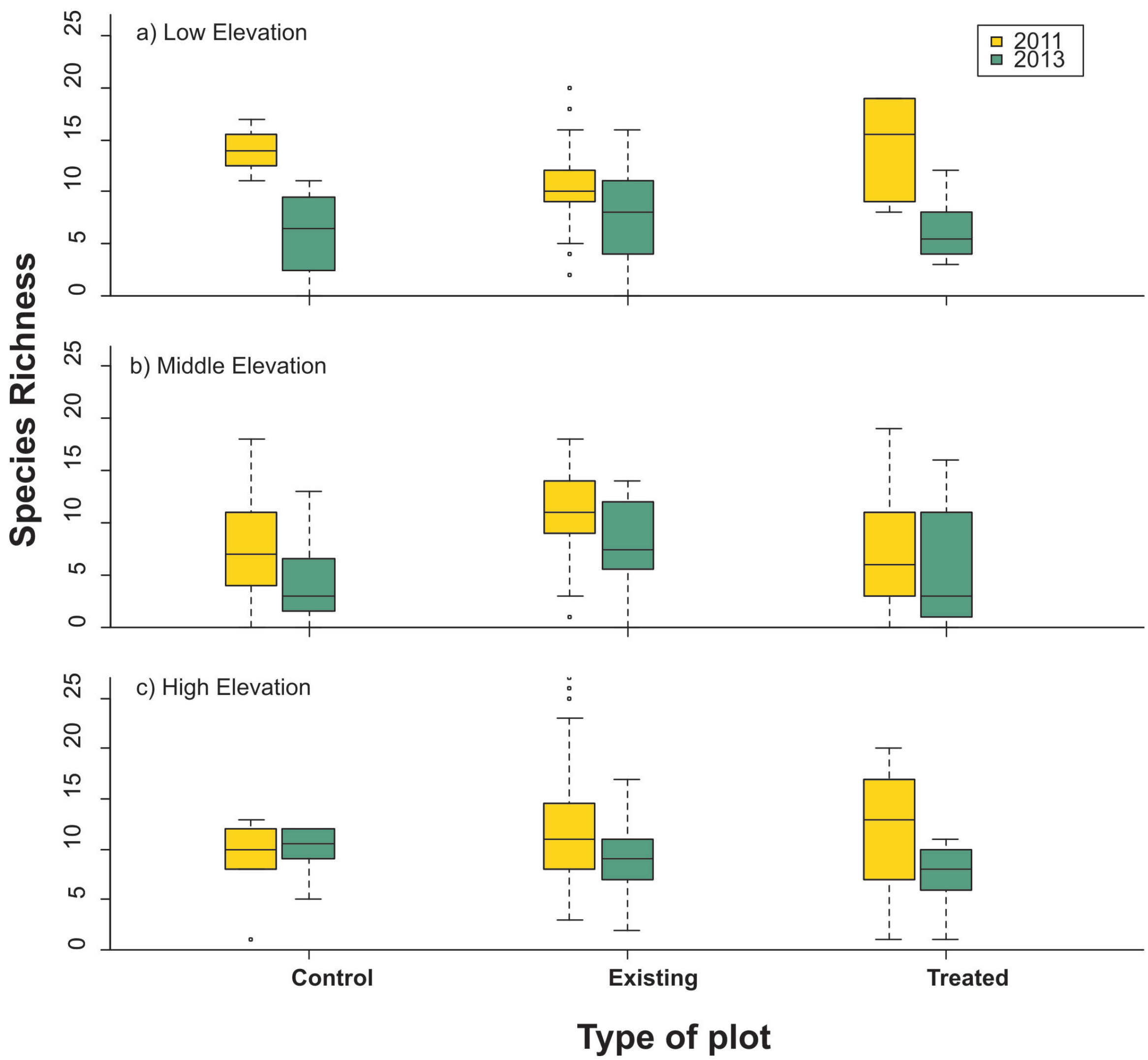

Figure 5-8: **Species richness of vegetation in control, existing, and treated sites across different elevation bands within the drawdown zone of Kinbasket Reservoir in 2011 and 2013. See Figure 5-6 for strata ranges. "Existing" sites are areas of natural vegetation occurring within the same strata as, but not directly associated with, the revegetation trials**

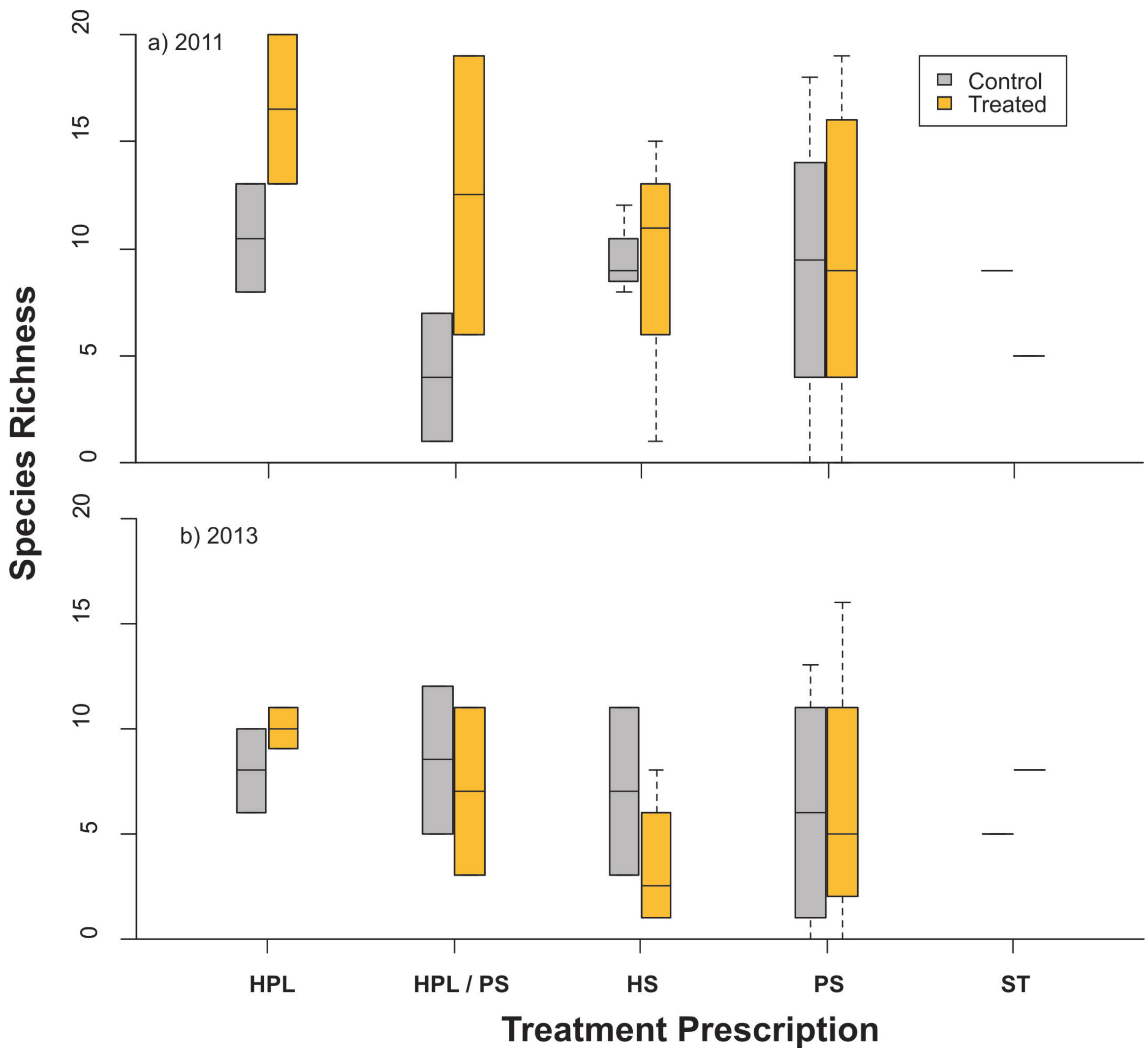

Figure 5-9: Species richness of vegetation for different treatment types in 2011 (upper) and 2013 (lower). See Table 4-2 for treatment codes

5.3.4. Species Diversity

Species diversity (Shannon's Index) was comparable for all site types (treatment, control, and existing) and elevation bands (Figure 5-10). Diversity did not change significantly between 2011 and 2013, although it appeared to be trending lower at low elevations and higher at high elevations (Figure 5-10). There was a possible increase in diversity for control sites in the HPL/PS treatment which was not mirrored in the treated sites (Figure 5-11). Likewise, there was a possible decrease in diversity for treated sites in the HS treatment which was not mirrored in the control sites (Figure 5-11). Diversity increased sharply in ST sites, but only one control and one treated site were sampled in this case. Differences were not statistically significant either between control and treated sites or among treatment prescriptions in 2011 or 2013. As in the case of cover and richness, these results indicate that revegetation treatments have had negligible effects on plant community structuring.

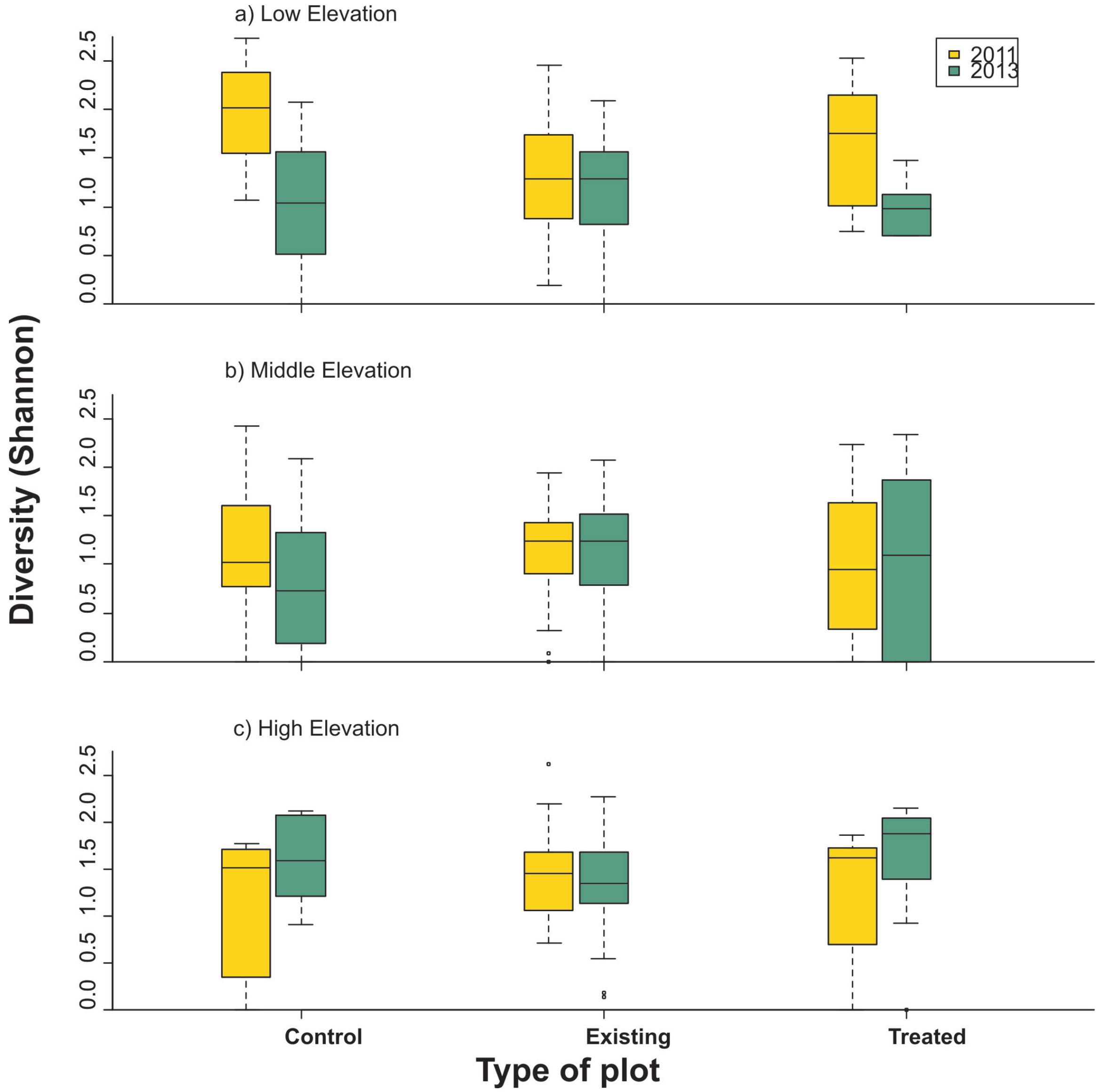

Figure 5-10: Species diversity (Shannon's index) of vegetation in control, existing, and treated sites across different elevation bands within the drawdown zone of Kinbasket Reservoir in 2011 and 2013. See Figure 5-6 for strata ranges. "Existing" sites are areas of natural vegetation occurring within the same strata as, but not directly associated with, the revegetation trials.

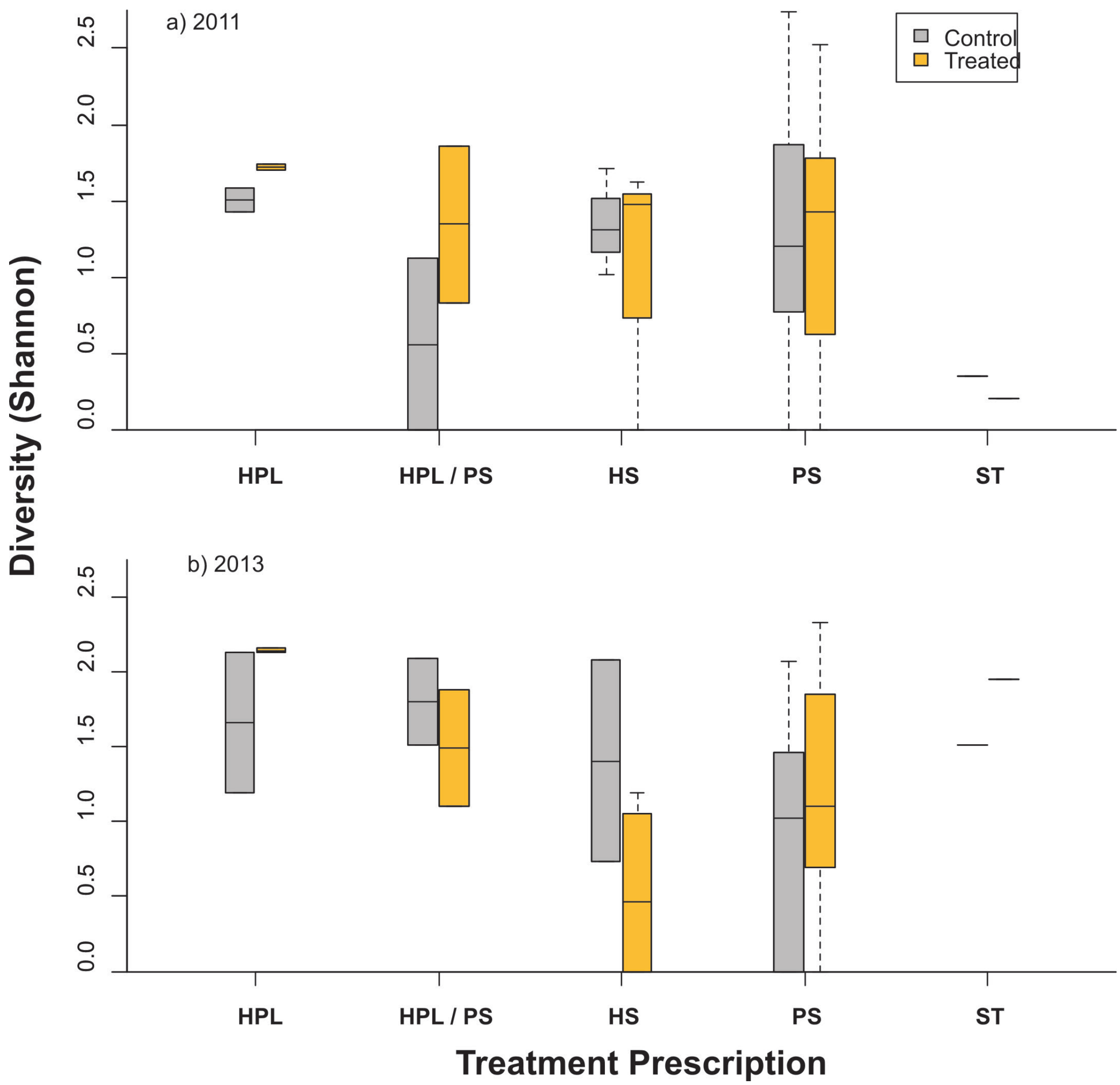

Figure 5-11: Species diversity (Shannon's Index) of vegetation for different treatment types in 2011 (upper) and 2013 (lower). See Table 4-2 for treatment codes

5.4. Vegetation Species Associations

Analyses of species associations using the Kendall W, K-Means partitioning, and canonical ordination found no significant differences between treatments and controls. While some species groups were consistently associated with different elevations, there was no distinction across elevations in the species compositions of treatment and control plots (results not shown).

5.5. Vegetation and Soil Nutrient Analysis

Vegetation samples were analyzed in the lab for content of calcium (Ca), magnesium (Mg), phosphorus (P), potassium (K), and total nitrogen (N). Because several of the more sparsely vegetated sites yielded insufficient plant material for the lab assay, samples sizes were small and thus the power to detect statistical differences was low. However, content of tested elements was very similar for treatment and control vegetation across all elevation bands (Figure 5-12 to

Figure 5-16). N content (Figure 5-16) followed a similar pattern to that of P (Figure 5-14), decreasing with increasing elevation both in 2011 and 2013. The N:P ratios < 15 suggest that vegetation communities at all elevations could be susceptible to N deficiency.

Results for both the vegetation carbon (C) assays and the soil nutrient assays were not available from the lab in time for incorporation into this report (the raw carbon data are appended for reference; Appendix 9-E). However, in view of the overall lack of treatment effects on vegetation cover and composition, we do not anticipate any significant effect of treatments on either vegetation carbon or soil nutrient content.

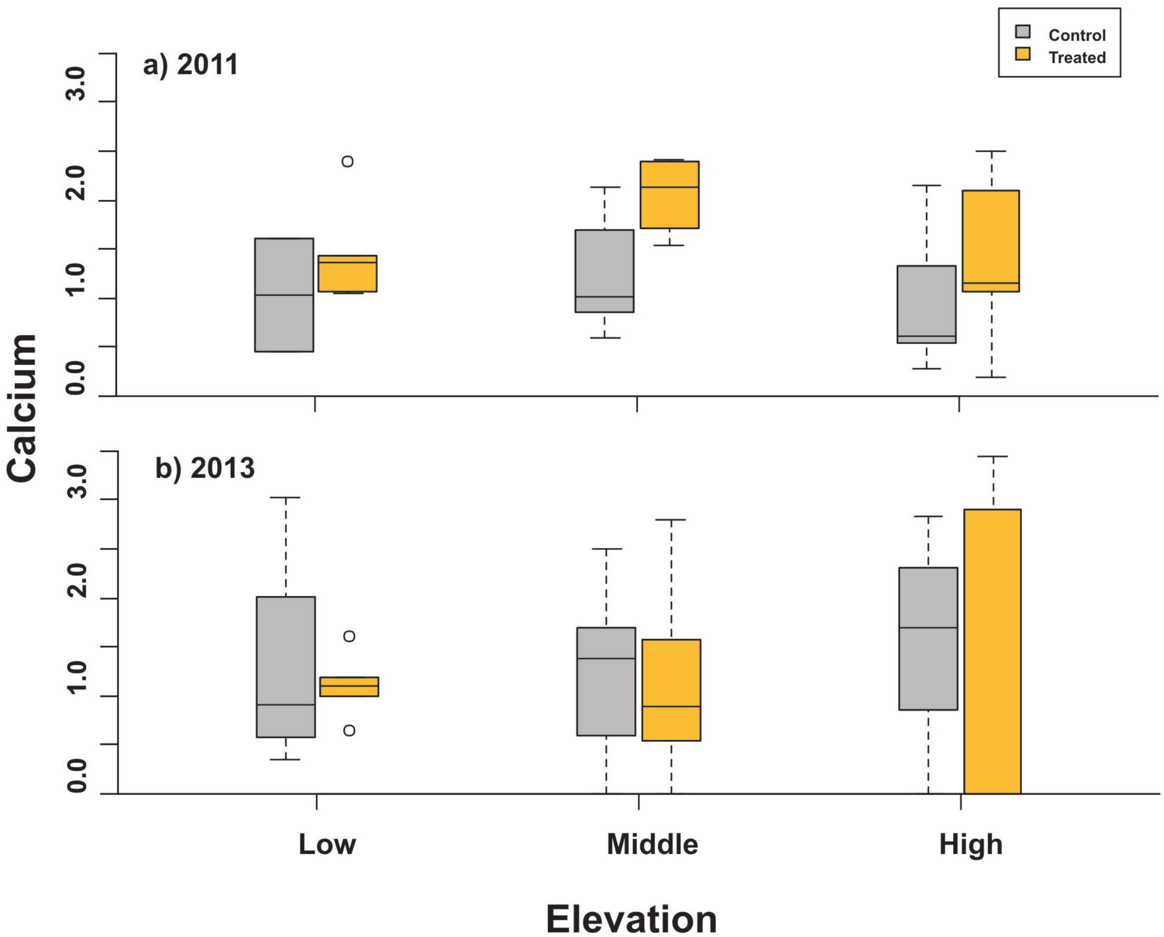

Figure 5-12: Calcium (Ca) content (% dry weight) of vegetation in control and treated sites across different elevation bands within the drawdown zone of Kinbasket Reservoir in 2011 (upper) and 2013 (lower). See Figure 5-6 for elevation strata ranges

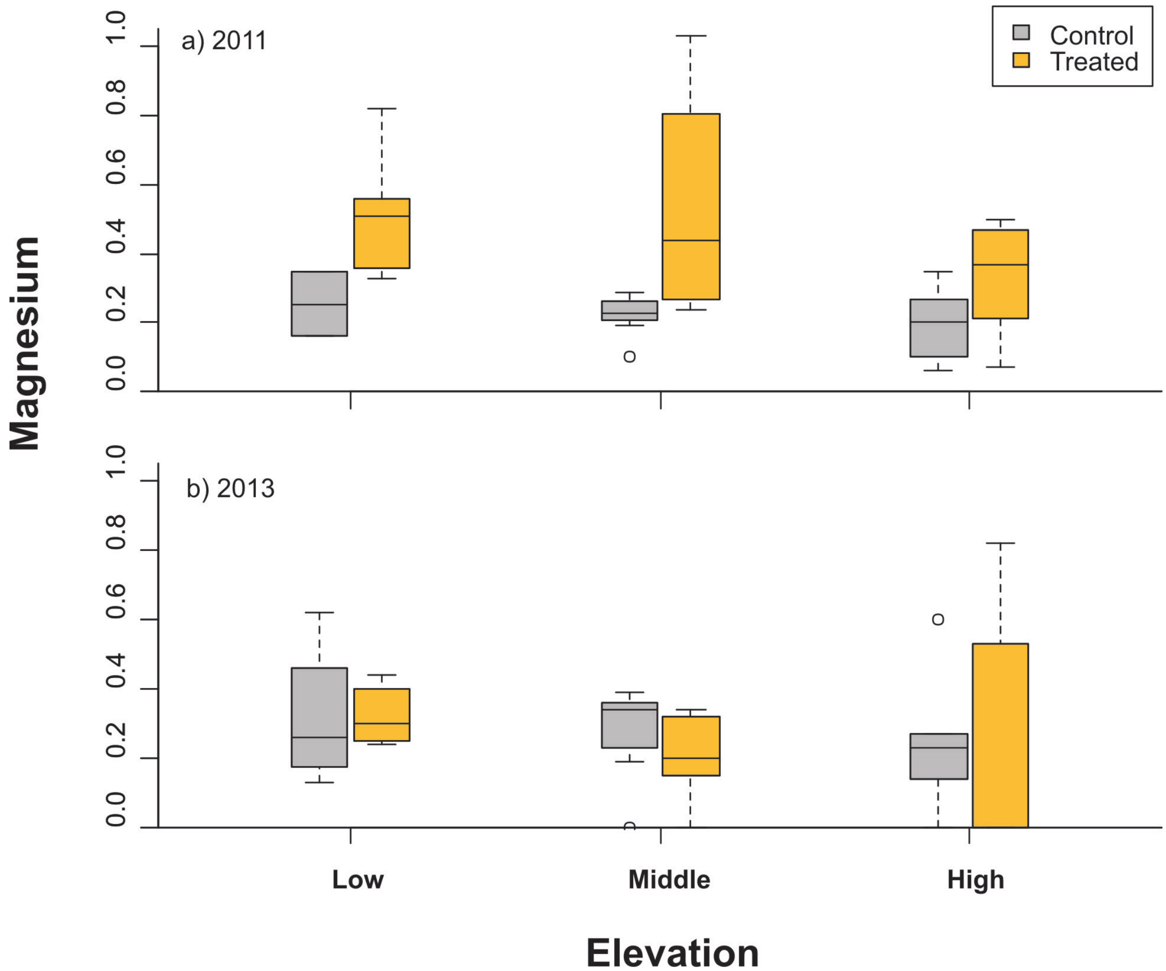

Figure 5-13: **Magnesium (Mg) content (% dry weight) of vegetation in control and treated sites across different elevation bands within the drawdown zone of Kinbasket Reservoir in 2011 (upper) and 2013 (lower). See Figure 5-6 for elevation strata ranges**

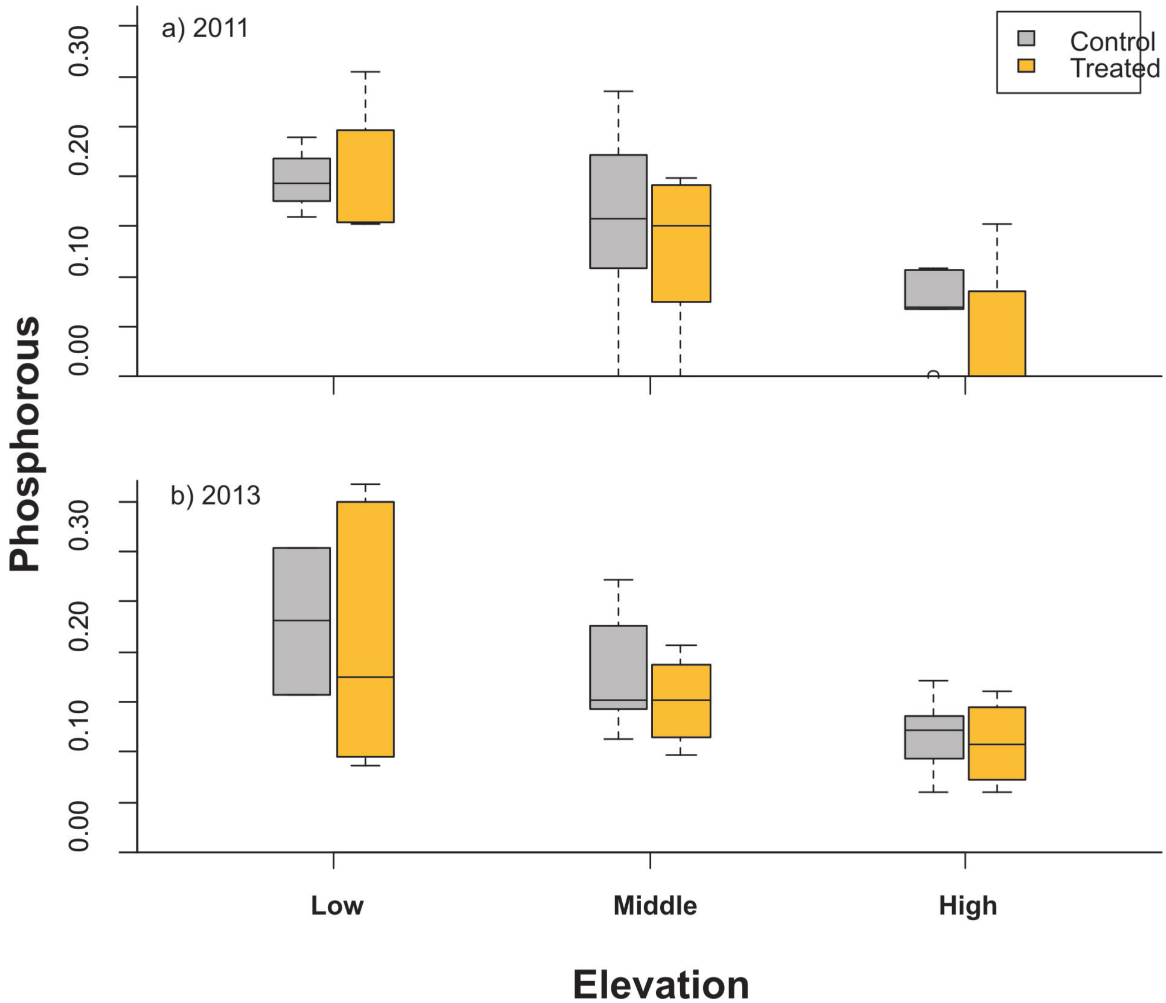

Figure 5-14: Phosphorous (P) content (% dry weight) of vegetation in control and treated sites across different elevation bands within the drawdown zone of Kinbasket Reservoir in 2011 (upper) and 2013 (lower). See Figure 5-6 for elevation strata ranges

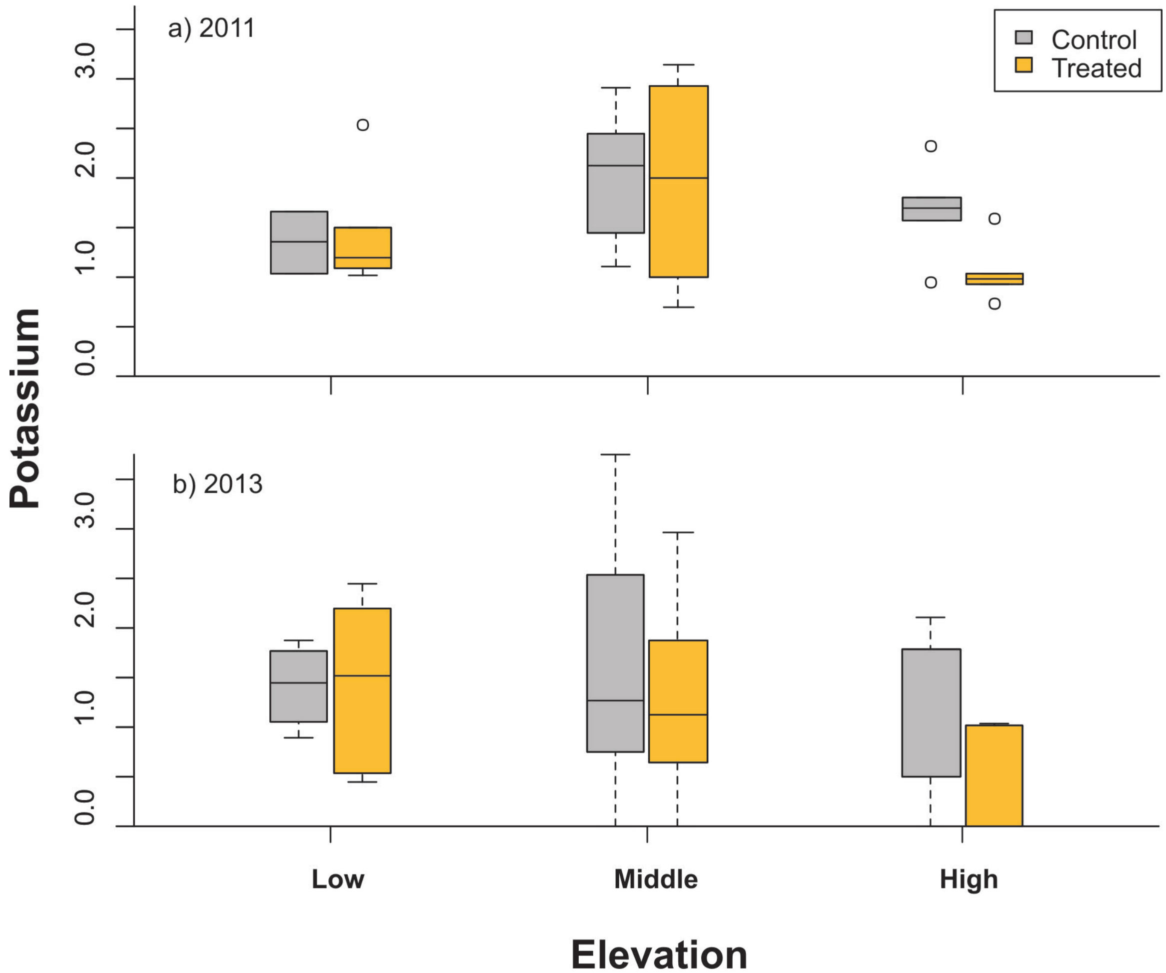

Figure 5-15: Potassium (K) content (% dry weight) of vegetation in control and treated sites across different elevation bands within the drawdown zone of Kinbasket Reservoir in 2011 (upper) and 2013 (lower). See Figure 5-6 for elevation strata ranges

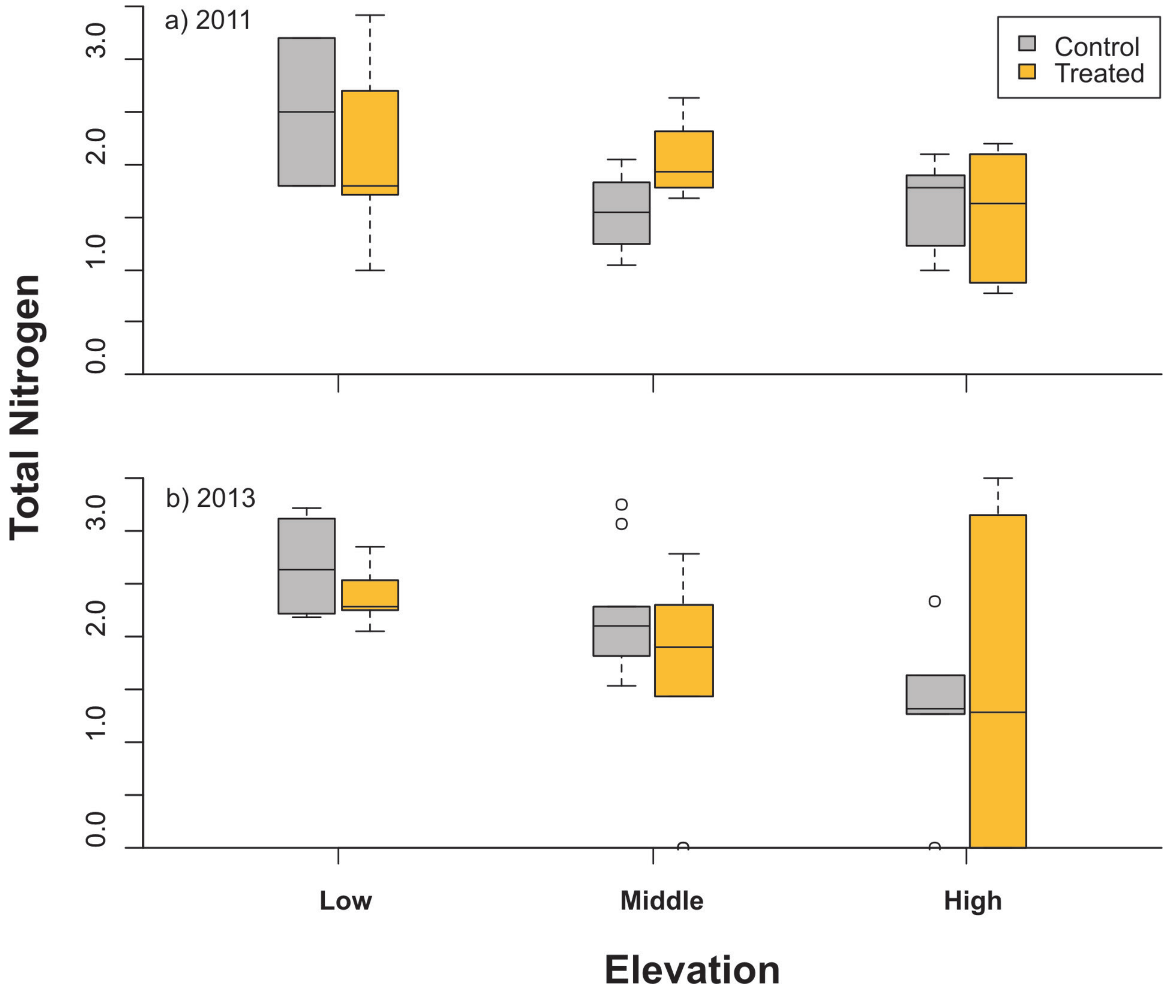

Figure 5-16: Total nitrogen (N) content (% dry weight) of vegetation in control and treated plots across different elevation bands within the drawdown zone of Kinbasket Reservoir in 2011 (upper) and 2013 (lower). See Figure 5-6 for elevation strata ranges

5.6. Reservoir Operations

The operation of Kinbasket Reservoir follows a similar pattern on an annual basis (Figure 5-1), but there is variation with respect to reservoir elevation and the timing and duration of inundation for each elevation band considered for CLBMON-9 (Table 5-2). Revegetation of the drawdown of Kinbasket Reservoir began in 2008 following the first full pool event in seven years. Between 2008 and 2010, Kinbasket was operated below full pool and habitats above 754 m ASL were not inundated during the growing season (Table 5-2). Starting in 2011, habitats at 754 m ASL were inundated for approximately 3.7 days with the number of days the upper elevations were inundated increasing substantially in 2012 (n = 42 days) and 2013 (data not available for draft report). In both 2012 and 2013 Kinbasket Reservoir was surcharged, meaning that maximum reservoir elevations exceeded the normal operating maximum of 754.38 m ASL. In 2012, the maximum elevation recorded was 754.68 m ASL (August 28, 2012) and in 2013, the maximum reservoir elevation recorded was XXX (data not available for report).

Table 5-2: Proportion of growing season (April 1 and September 30; n = 183 days) that each elevation band was inundated by Kinbasket Reservoir. For example, in 1997, elevations between 741 and 742 m ASL were inundated for 107 of 183 days (58 percent) of the time. This means that this elevation band was exposed for 42 per cent (~77 days) in 1997. Shaded cells indicate that the elevation band was not inundated in that year. 2013 data through August 29

m ASL	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
741-742	0.58	0.60	0.49	0.44	0.21	0.44	0.40	0.34	0.55	0.59	0.55	0.48	0.53	0.46	0.54	0.54	0.35
742-743	0.58	0.58	0.47	0.43	0.05	0.44	0.37	0.23	0.54	0.58	0.54	0.46	0.51	0.45	0.52	0.53	0.34
743-744	0.57	0.56	0.45	0.40		0.43	0.26	0.19	0.51	0.56	0.52	0.44	0.48	0.43	0.51	0.52	0.33
744-745	0.55	0.54	0.44	0.39		0.42	0.09	0.16	0.50	0.54	0.50	0.42	0.46	0.42	0.49	0.50	0.32
745-746	0.54	0.52	0.43	0.37		0.40		0.11	0.48	0.52	0.49	0.39	0.43	0.39	0.48	0.50	0.31
746-747	0.51	0.50	0.42	0.36		0.39		0.07	0.46	0.51	0.48	0.37	0.40	0.37	0.46	0.49	0.30
747-748	0.49	0.48	0.40	0.30		0.37			0.41	0.49	0.46	0.34	0.37	0.35	0.45	0.47	0.28
748-749	0.48	0.45	0.39	0.17		0.35			0.35	0.48	0.44	0.32	0.34	0.33	0.43	0.46	0.27
749-750	0.45	0.40	0.37	0.04		0.32			0.28	0.45	0.43	0.27	0.31	0.31	0.42	0.45	0.24
750-751	0.44	0.29	0.34			0.23			0.16	0.43	0.42	0.23	0.24	0.27	0.40	0.44	0.21
751-752	0.42	0.14	0.32			0.06				0.37	0.40	0.18	0.16	0.19	0.38	0.43	0.17
752-753	0.39		0.28								0.36			0.03	0.35	0.42	0.13
753-754	0.34		0.19								0.19			0.01	0.32	0.32	0.08
>754	0.18		0.05								0.06				0.02	0.23	0.02
>754.38																0.17	

To assess the capability of vegetation growth during the growing season, the number of growing days per month and year were assessed relative to reservoir operations. The proportion of growing days available to each elevation band, month, and year for the growing season is shown in Table 5.3. All elevations were exposed for most of or all of April, May, and June each year with exposure time decreasing in July and August. By August most of the area between 741 and 751 m ASL is under water. At this point, the proportion of growing degree days is assumed to be 0 per cent. In the mid-summer growing months of June, July, and August, there was a substantial reduction in the proportion of available growing days during the 2011-2013 period relative to the three years prior (2008-2010).

The proportion of growing days per elevation band was slightly higher in 2013 than in 2011 and 2012, but still well below the proportions experienced from 2008 to 2010. The effect of reduced growing degree days on vegetation community establishment and development has not yet been studied, although it is reasonable to suspect that the increase in reservoir elevations and corresponding reduction of growing degree days represents a limiting factor for drawdown zone vegetation (see Hawkes et al. 2010, 2013). We would expect any impacts to be exaggerated for vegetation treatments applied between 2010 and 2013, given that those transplants were likely still suffering from transplant shock (Shumar and Anderson 1987) when the number of overall growing days in the drawdown zone was reduced.

Table 5-3 Proportion of growing days available during the growing season (April 1 through September 30) for each implementation year of CLBMON-9 for elevations between 741 and 754 m ASL. Green indicates little or no impact on exposure time, yellow indicates a moderate to strong effect, and red indicates strong to complete reduction in growing degree days. 2013 data through August 29

		Elevation (m ASL)													
Month	Year	741	742	743	744	745	746	747	748	749	750	751	752	753	754
April	2007	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2008	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2009	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2010	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2011	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2012	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2013	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
May	2007	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2008	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2009	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2010	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2011	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2012	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2013	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
June	2007	0.70	0.80	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2008	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2009	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2010	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2011	0.80	0.90	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2012	0.80	0.83	0.90	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2013	0.87	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
July	2007	0.00	0.00	0.00	0.00	0.10	0.16	0.26	0.35	0.42	0.52	0.61	0.61	0.84	1.00
	2008	0.16	0.26	0.35	0.48	0.65	0.81	0.94	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2009	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2010	0.23	0.32	0.42	0.52	0.65	0.77	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2011	0.00	0.00	0.00	0.06	0.16	0.23	0.32	0.42	0.52	0.61	0.74	0.74	1.00	1.00
	2012	0.00	0.00	0.00	0.00	0.00	0.06	0.16	0.23	0.26	0.32	0.39	0.39	0.55	0.71
	2013	0.00	0.00	0.00	0.06	0.10	0.19	0.26	0.35	0.52	0.71	0.90	0.90	1.00	1.00
August	2007	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.65
	2008	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.35	0.61	0.90	0.90	1.00	1.00
	2009	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.16	0.35	0.87	0.87	1.00	1.00
	2011	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	1.00
	2012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2013	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.84
September	2007	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00
	2008	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00
	2009	0.60	0.73	0.83	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.97	1.00
	2011	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.90
	2012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.90
	2013	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Totals	2007	0.32	0.34	0.36	0.37	0.40	0.42	0.45	0.48	0.50	0.53	0.56	0.56	0.76	0.93
	2008	0.41	0.43	0.46	0.49	0.53	0.57	0.60	0.63	0.70	0.77	0.83	0.83	1.00	1.00
	2009	0.94	0.96	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2010	0.48	0.50	0.53	0.55	0.59	0.62	0.66	0.69	0.72	0.76	0.87	0.87	1.00	1.00
	2011	0.33	0.35	0.36	0.38	0.40	0.42	0.44	0.46	0.48	0.50	0.52	0.52	0.60	0.98
	2012	0.30	0.30	0.31	0.32	0.33	0.35	0.37	0.39	0.40	0.41	0.43	0.43	0.57	0.66
	2013	0.33	0.34	0.35	0.37	0.37	0.40	0.42	0.44	0.48	0.53	0.58	0.58	0.72	0.80

Annual reservoir maximums have increased steadily since the initiation of planting in 2008, reaching or exceeding the normal operating maximum in both 2012 and 2013 (Figure 5-17). Hawkes et al. (2010) reported that following the full pool event in 2007, there was a notable die-off of woody shrubs in upper elevation wetland communities such as the WS, a decline in woody cover that appears to have been exacerbated by the succession of high water events since 2010 (Hawkes et al. 2013). It is probable that the recent operating regime has had at least a similar, if not a greater, detrimental impact on survivorship of live stakes of woody shrub species planted in the upper elevation zones. Stakes planted in 2008 and 2009 likely had insufficient time to develop the root systems needed to cope with the physiological and mechanical stresses associated with prolonged inundation (alternating with extreme drought) in the one or two years available to them prior to the reservoir achieving full pool.

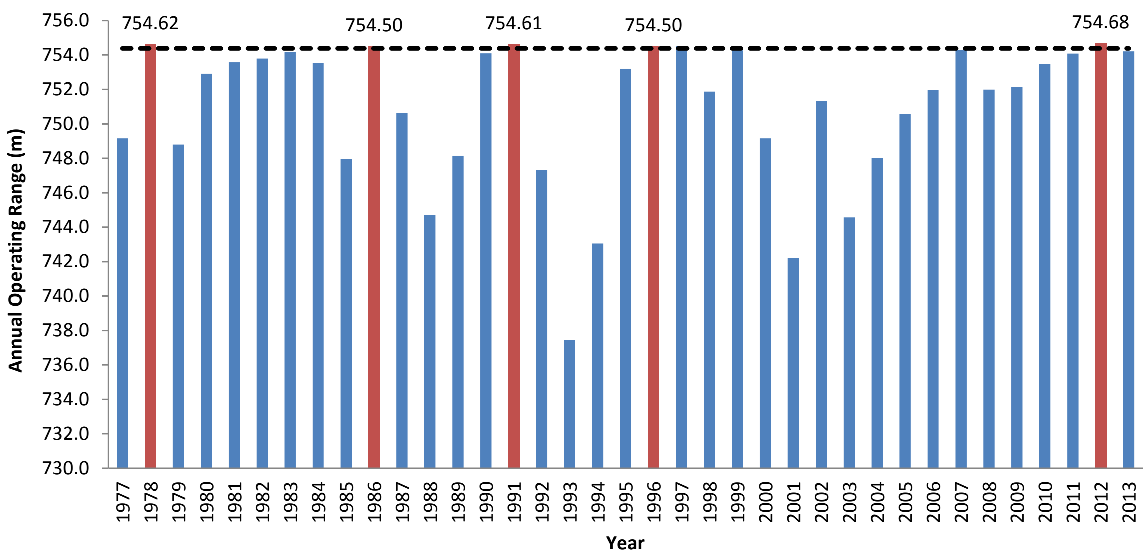

Figure 5-17: Maximum reservoir elevations recorded for Kinbasket Reservoir 1977 through 2013 (top) and annual draught or operating range (bottom). 2013 data for January 1 to August 29. The black dashed line represents the normal operating maximum. Red bars indicate years when that maximum was exceeded

Reservoir elevations did not only vary from year to year, but the rate at which the reservoir filled also varied among implementation years (Figure 5-18). An example is 2011, when the reservoir was slow to fill between 753 and 754 m ASL relative to other full pool years. For years when Kinbasket was operated at or beyond normal full pool (2007, 2011, 2012, and 2013) the rate of filling was generally more rapid than in years when the reservoir was not operated at full pool (2008, 2009, and 2010).

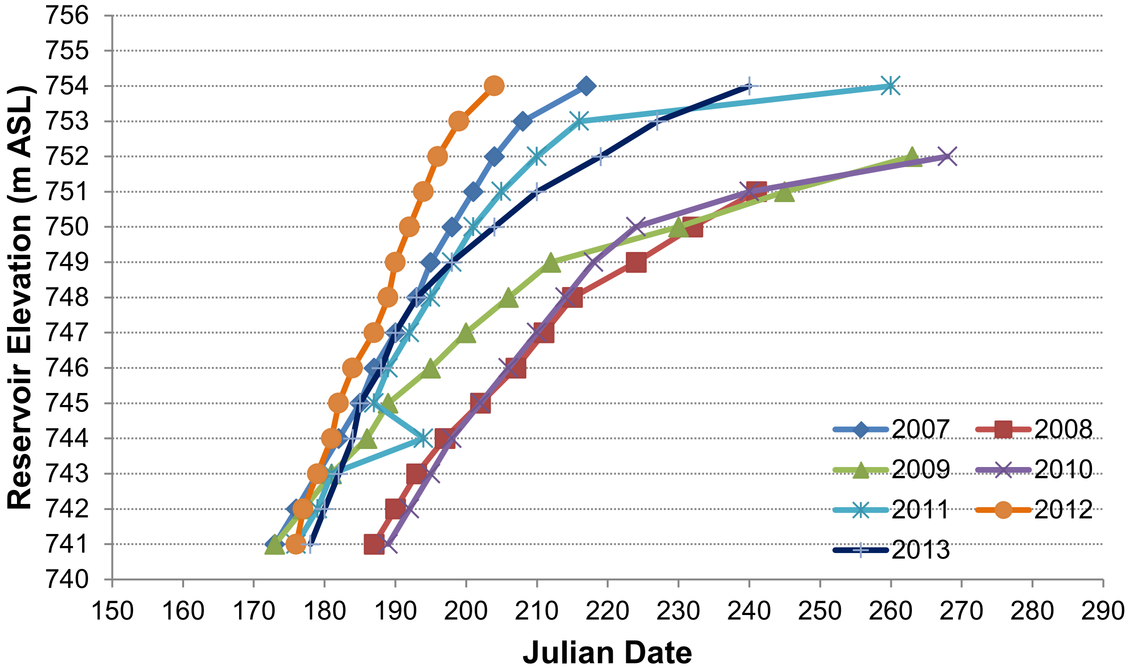

Figure 5-18: Rate of reservoir filling between 741 and 754 m ASL between 2007 and 2013 relative to the Julian date

The timing of inundation relative to elevation varied between years, with the reservoir reaching upper elevation bands almost two weeks earlier in 2012 than in 2011, and a month earlier than in 2010 (Table 5-4). In fact, inundation occurred earlier in 2012 than in any year since 1977, for all elevation bands. It also stayed for longer at high elevations: water levels remained above 754 m for 43 days in 2012, an unprecedented occurrence (Table 5-5). This suggests that the newer planting treatments (i.e., those planted since 2010) have had less chance to become properly established prior to being flooded, while also being subjected to longer flood periods post-planting, both factors that could affect their current and future performance.

Table 5-4: Dates at which each elevation band was inundated per year. "--" indicates elevation band not inundated

Elevation	Year and Date						
(m ASL)	2007	2008	2009	2010	2011	2012	2013
741	Jun-22	Jul-06	Jun-26	Jul-08	Jun-25	Jun-25	Jun-27
742	Jun-25	Jul-09	Jun-30	Jul-11	Jun-28	Jun-26	Jun-29
743	Jun-28	Jul-12	Jul-05	Jul-14	Jun-30	Jun-28	Jul-01
744	Jul-01	Jul-16	Jul-08	Jul-17	Jul-03	Jul-01	Jul-03
745	Jul-04	Jul-21	Jul-14	Jul-21	Jul-06	Jul-02	Jul-04
746	Jul-06	Jul-26	Jul-19	Jul-25	Jul-08	Jul-04	Jul-07
747	Jul-09	Jul-30	Jul-24	Jul-29	Jul-11	Jul-07	Jul-09
748	Jul-12	Aug-03	Jul-31	Aug-02	Jul-14	Jul-09	Jul-12
749	Jul-14	Aug-12	Aug-06	Aug-06	Jul-17	Jul-10	Jul-17
750	Jul-17	Aug-20	Aug-18	Aug-12	Jul-20	Jul-12	Jul-23
751	Jul-20	Aug-29	Sep-02	Aug-28	Jul-24	Jul-14	Jul-29
752	Jul-23 to Sept-26	--	Sep-24	Sep-25	Jul-29	Jul-16	Aug-07
753	Jul-28 to Aug-29	--	--	Sep-30	Aug-04	Jul-19 to Sept-15	Aug-15
754	Aug-4 to Aug-16	--	--	--	Sept-17 to Sept-19	Jul-24 to Sept-5	Aug-27

Table 5-5. Inundation duration, as indicated by the total number of annual days for which water depths were greater than 0 m, by elevation band and year. *2013 data up to August 29

Elevation (m ASL)	Year						
	2007	2008	2009	2010	2011	2012	2013*
741	101	87	97	85	98	98	64
742	98	84	93	82	95	97	62
743	95	81	88	79	93	95	60
744	92	77	85	76	90	92	58
745	89	72	79	72	87	91	57
746	87	67	74	68	85	89	54
747	84	63	68	64	82	86	52
748	81	59	62	60	79	84	49
749	79	50	56	56	76	83	44
750	76	42	44	50	73	81	38
751	73	33	29	34	69	79	32
752	66	0	11	6	64	77	23
753	34	0	0	1	58	58	15
754	11	0	0	0	3	43	3

Along with inundation timing and duration, the depth of inundation, which determines the amount of available light, can affect belowground biomass, stem density, and reproductive output (Hawkes et al. 2013). Water depth data for June and/or July were compared among years for each elevation band to assess how inundation depth immediately following treatment might affect vegetation establishment and development. Inundation was relatively deep in 2012 for elevations between 741 and 747 m ASL, but especially for elevations > 747 m ASL (Figure 5-19). Vegetation prescriptions applied in 2012 between 741 and 754 m ASL potentially experienced higher degrees of light stress in the year of planting compared to prescriptions applied in 2008, 2009, or 2010. Nevertheless, the high attrition rates obtained for all stocks planted between 2008 and 2011, regardless of the year planted, suggests that low survival rates cannot be solely attributed to increased inundation depth and duration in the drawdown zone since 2011.

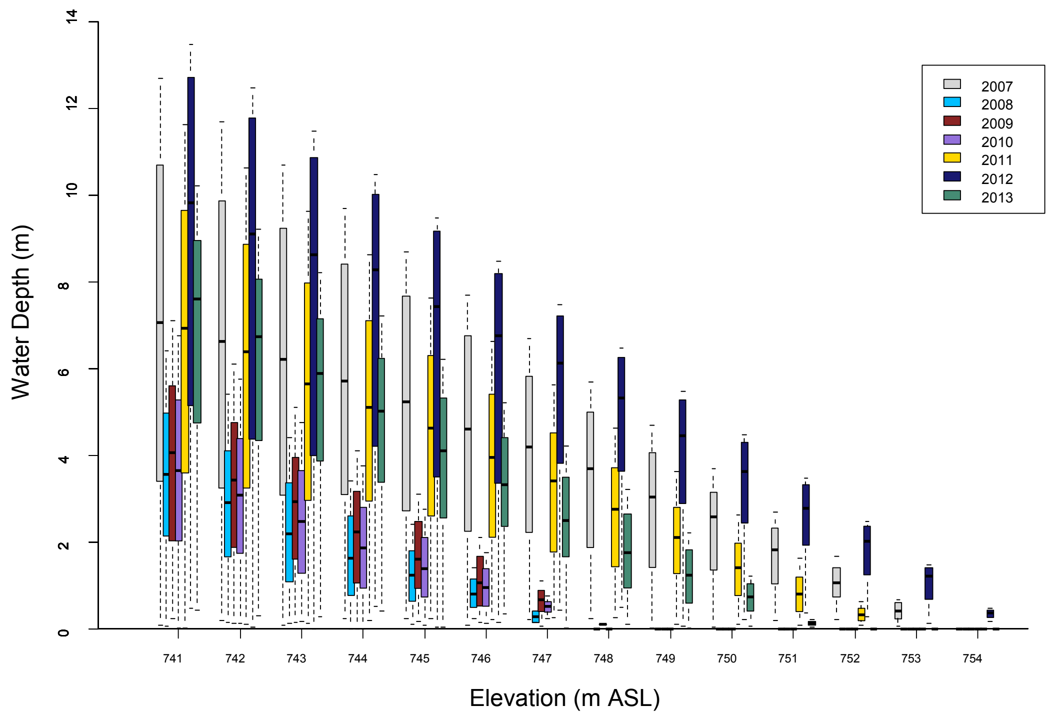

Figure 5-19: Water depths per elevation in Kinbasket Reservoir over time in June and July, from 2008 to 2013. Data displayed exclude the dates when water elevations were lower than the given elevation band; therefore, sample sizes included vary between elevation bands and years. Average water depths differed significantly among elevation bands and years (F = 24.3, p = 0.0001; and, F = 66.1, p = 0.0001, respectively). Elevations above 747 m were not tested since water depth was 0 m in 2008, 2009, and 2010

6.0 DISCUSSION

6.1. Summary of Revegetation Effectiveness

Results of this report largely confirm the 2011 assessment of revegetation effectiveness (Fenneman and Hawkes 2012). To date, only a few treatments have met with partial establishment success; the majority have struggled or, in many cases, been completely unsuccessful. Sedge plug survivorship within planted stands sampled by CLBMON-9 declined from approximately 40 per cent in the two years following planting, to < 10 per cent three years post-planting, to less than five per cent four to five years post-planting. Live stakes of deciduous shrubs (willows, alder, and cottonwood) appear to have fared worse, with none found surviving five years after planting. The fates of deciduous seedling plugs that were planted in 2010 at two upper elevation sites in Bush Arm (south reservoir region; Keefer et al. 2011) were not monitored by this project and are unknown.

Not surprisingly, given the low rates of survivorship across planting treatments, revegetation programs to date have had little impact on the distribution of plant communities in the drawdown zone of Kinbasket Reservoir. No statistically significant difference was detected in either per cent cover of vegetation, species richness, or species diversity between treatment and control sites in any of the 12 community types that were sampled, regardless of elevation, geographic region, or prescription type. In all but one of these communities (CO), the per cent cover of vegetation was actually higher or equivalent in control sites than in treated sites. Pooling data for all vegetation communities, overall cover decreased somewhat at higher drawdown zone elevations for both treated and control areas between 2011 and 2013, while remaining unchanged or increasing slightly at low and mid elevations.

Although treated communities are still, in theory, in the early developmental stage (ranging in “age” from two to five years), the high mortality rates of transplanted stock suggest that the current revegetation approach has limited potential, under the current operating regime, to improve the remediation and expansion of vegetation communities in the drawdown zone.

Several factors associated with reservoir operations likely contributed to the poor performance of treatment sites in specific areas of the drawdown zone. These include localized impacts from erosion, deposition, scouring by woody debris, mechanical disturbance during the routine removal of accumulated woody debris (e.g., Windfall Creek), and recreational impacts from ATV use (e.g., Yellow Jacket Creek and some areas of the Valemount Peatland). Across the entire reservoir, the failure of plantings can also be attributed to the operating regime itself, namely, the timing, frequency, duration, and depth of inundation. Given that the operating regime is unlikely to change significantly in the near future, we expect that the prevailing conditions will continue to affect the establishment and development of vegetation in the drawdown zone and will make it difficult to revegetate the drawdown zone using the approach taken to date. This includes the choice of species and locations for revegetation, which may have contributed to the low success of the revegetation treatments (Keefer et al. 2011, Fenneman and Hawkes 2012).

Nevertheless, we feel that the opportunity does exist to modify operations to more effectively achieve revegetated communities at the site level in the future. In addition to making changes to the way planting is done, we suggest that the act of removing woody debris from selected sites in the drawdown zone may be a more cost-effective method of facilitating natural colonization and regeneration processes than direct stocking. Furthermore, the CLBMON-9 program is well situated to undertake an assessment of how woody debris removal can contribute to the establishment and development of vegetation in the drawdown zone. These topics are discussed in further details below, under Management Questions, and in the recommendations.

6.2. Management Questions

All management questions (MQs) pertaining to the revegetated areas component of the CLBMON-9 monitoring program (2.1.2) were addressed, or in some cases, will be addressed once a longer time series is available. MQ status is summarized in Table 6-1, with a more detailed discussion following below. Discussion of MQs pertaining specifically to existing vegetation (2.1.1) have been deferred to the associated program CLBMON-10, following the recommendation of Fenneman and Hawkes (2012).

Table 6-1: CLBMON-9 Status of management questions and hypotheses

Management Question (MQ)	Management Hypotheses			Will MQ Be Addressed?	Data Required	Current Status	Preliminary Results
1. What is the quality and quantity of vegetation in revegetated areas compared to untreated areas, based on an assessment of species distribution, diversity, vigour, abundance, biomass, and cover?	H_{01A}	H_{01B}	H_{01C}	Yes	Field data (cover and biomass quadrats); lab data	Ongoing, but approaching ability to answer this MQ (anticipated response: "NO SIGNIFICANT DIFFERENCE")	Some sedge plugs surviving in limited areas, but no significant differences detected in quality or quantity of vegetation between treated and untreated sites.
2. What are species-specific survival rates under current operating conditions (i.e., what are the tolerances of revegetated plant communities to inundation timing, frequency, duration and depth)?	H_{01A}			In part	Field data (survivorship data for different treatment types); controlled experimental data for separating out potentially confounding factors	Ongoing, but approaching ability to answer this MQ (anticipated response: "LOW TO ZERO SURVIVAL")	Steep decline in survivorship of plug seedlings and live stakes each year following planting; ~4 per cent of plugs surviving 4 yrs. after planting; large-scale mortality of live stakes.
3. What environmental conditions, including the current operating regime (i.e., timing, frequency, duration and depth of inundation), may limit or improve the remediation and expansion of vegetation communities in the drawdown zone?	H_{01A}	H_{01B}	H_{01C}	Maybe	Field data, including time series data from CLBMON-10 (minimum of 5 years times series data), hydrological data	Ongoing, but approaching ability to identify limiting conditions (anticipated response: "THE CURRENT OPERATING REGIME IS THE MOST IMPORTANT, THOUGH NOT THE ONLY, VARIABLE LIMITING REVEGETATION SUCCESS IN THE DRAWDOWN ZONE"); several more years of field data, and likely a change in research direction, needed to identify environmental conditions (e.g., woody debris removal) that would improve remediation and expansion of vegetation communities	Under the current operating regime, revegetation success has been low and declining over time for all combinations of region, elevation, and planting prescription. Revegetation success of CLBWORKS-1 is likely limited by a combination of timing, frequency, duration and depth of inundation; erosion, sedimentation, and woody debris accumulation and scouring; choice of species used for revegetation; and choice of sites targeted for revegetation.

Management Question (MQ)	Management Hypotheses			Will MQ Be Addressed?	Data Required	Current Status	Preliminary Results
4. What is the relative effectiveness of the different revegetation treatments, as applied through CLBWORKS-1, at increasing the quality and quantity of vegetation in the drawdown zone?			H_{01C}	Maybe	Field data (cover and biomass quadrats, survivorship plots); lab data	Ongoing, but approaching ability to answer this MQ (anticipated response: "ALL ARE INEFFECTIVE"); statistical assessment hampered by small sample sizes and lack of replication/stratification associated with CLBWORKS-1. A review of the effectiveness of the current revegetation program is presented in this report	Widely variable results among individual sites and treatments, but the sedge plug treatment (PS) appears to be the only treatment type to have achieved moderate success in limited locales.
5. Does implementation of the revegetation program result in greater benefits (e.g., larger vegetated areas, more productive vegetation) than those that could be achieved through natural colonization alone?	H_{01A}	H_{01B}	H_{01C}	Maybe	Time series field data (including data from CLBMON-10) specifically targeting natural colonization in response to physical works (no such data currently available)	Ongoing, but approaching ability to answer this MQ (anticipated response: "NO"). A review of the effectiveness of the current revegetation program is presented in this report.	There has been a small amount of moderately successful plug establishment in limited areas, indicating that the revegetation program has resulted in a minor net benefit with respect to size and productivity of some vegetated areas. However, opportunities may exist for facilitating natural colonization processes through targeted physical works that could potentially create greater benefits than the revegetation program. For example, reducing woody accumulation and taking other measures to promote natural regeneration may be a more effective long-term approach to achieving revegetation objectives than out-planting, as discussed in Sections 6.0 and 7.0 of this report.

Management Question (MQ)	Management Hypotheses			Will MQ Be Addressed?	Data Required	Current Status	Preliminary Results
6. Is there an opportunity to modify operations to more effectively maintain revegetated communities at the site level in the future?	H_{01A}	H_{01B}	H_{01C}	Maybe	Review of existing literature, past reports, and current status of the revegetation program; data on the effectiveness alternative shoreline management options	Ongoing, but approaching ability to answer this MQ (anticipated response: "NO"). It is unlikely that modifying operations at this point will have any desired effects, because the revegetation treatments have already largely failed.	Under the current operating regime, revegetation success has been low and declining over time for all combinations of region, elevation, and planting prescription. Preliminary results suggest that adjusting the timing and reducing the duration and depth of inundation could translate into increased success for future revegetation attempts.

H_{01A}: There is no significant difference in vegetation establishment (based on species distribution, diversity, vigour, biomass and abundance) at control versus treatment locations.
H_{01B}: There is no significant difference in the cover of vegetation in control versus treatment areas.
H_{01C}: There is no significant difference in the cover of vegetation communities and vegetation establishment (based on species distribution, diversity, vigour, biomass and abundance) arising from different revegetation prescriptions.

6.2.1. MQ 1: What is the quality and quantity of vegetation in revegetated areas compared to untreated areas, based on an assessment of species distribution, diversity, vigour, abundance, biomass, and cover?

Anticipated response, based on preliminary results: "No significant difference."

Based on our comparisons of plant abundance and diversity/richness metrics between treated and control sites in both 2011 and 2013, there is little evidence to indicate that either the quality or quantity of native vegetation in the Kinbasket Reservoir drawdown zone has increased as a result of the CLBWORKS-1 program. In fact, both plant cover and species richness in treatment sites generally decreased since 2011, mirroring the trend in control sites. This trend was fairly consistent for both controls and treatments across community type, elevation, and prescription type. Only in some low elevation sites and in hand-seeded areas were there marginal increases in cover, but there was no indication that differences were due to treatment.

Our preliminary results indicate that the CLBWORKS-1 program has failed to achieve the objective of maximizing vegetation growth within the drawdown zone of Kinbasket Reservoir. However, all the planted stands are five years old or less (2008 being the first treatment year) and thus may still be developing; as of 2013, we are only able to evaluate the initial stages of the developmental trajectory. Those few sites (mostly located in Bush Arm) that experienced some success in planting survivorship conceivably could, in the future, develop community characteristics that distinguish them from non-treated areas.

Consequently, an argument can be made for continuing to monitor areas where there has been a small degree of establishment success, on the chance that doing so helps to resolve the still unanswered question of whether revegetated areas can improve the quality of the drawdown zone environment in measurable ways. However, the current opportunities for monitoring such effects are quite limited due to the small remaining sample size and past inconsistencies in the CLBWORKS-1 planting methodology, including a lack of adequately stratified treatments.

There are, unfortunately, few examples of successful riparian reclamation in other northern temperate zone reservoirs on which to base predictions about post-reclamation community development; most research remains at the experimental stage (e.g., Allen and Klimas 1986; Jackson et al. 1995; Johansson and Nilsson 2002; MacKillop 2003; Abrahams 2006; Lu et al. 2010; Yang et al. 2012; Liu and Willison 2013). However, it is known that reservoir drawdown and re-flooding alter successional processes, create continued disturbance in the system, and affect physical and chemical parameters of the substrates (Abrahams 2006). Furthermore, plant responses to such disturbances are likely highly site-specific. Teasing out these responses probably calls for a more experimental approach than the rather ad-hoc on with which CLBMONWORKS-1 revegetation treatments were applied around the reservoir. The experience that has been gained from this process can nevertheless be used in an adaptive management framework to make constructive modifications to the program so that better results can be achieved in the future.

6.2.2. MQ 2: What are species-specific survival rates under current operating conditions (i.e., what are the tolerances of revegetated plant communities to inundation timing, frequency, duration and depth)?

Anticipated response, based on preliminary results: "Low survival to zero survival."

Survival rates under CLBWORKS-1 were very low (< 10 per cent to zero survivorship four years post-planting) for most of the planting approaches attempted (e.g., live deciduous staking, sedge seedling plugs, hand-planted stakes mixed with plug seedlings, hand seeding) irrespective of geographic region, elevation band, or community type. Live stakes exhibited almost complete mortality. On sites where sedge plugs have survived, overall vigour generally declined with time, a trend we anticipate will continue. It appears that sedge plugs have been unable to achieve sufficient root development needed to cope with the extreme physiological and mechanical stresses associated with inundation in the few short weeks available to them following out-planting, prior to the reservoir filling. For Kellogg's sedge and other perennial graminoids, use of older (> 1 yr), more robust nursery stock might yield better results in the future. A new phase of planting treatments implemented in 2013 (Adama 2013) should provide useful information for testing the validity of this hypothesis once post-planting monitoring commences.

Hand and ATV seeding trials, and deciduous seedling plugs, were not monitored under the CLBMON-9 program because we could not distinguish treatment plants from natural regeneration. There were some preliminary indications through CLBWORKS-1 (Keefer et al. 2011) that deciduous seedling plugs from 2010 were faring better than the live stake treatments one year post-planting (there has been no subsequent monitoring to back up this result). However, we anticipate low success rates for broadcast seeding, because many seeds would not have had an opportunity to germinate and become rooted prior to being blown to other areas or washed away in the summer re-flooding event.

Identifying tolerance levels of the various treatments to specific elements of the operating regime is challenging without benefit of data from controlled experiments (such as those conducted in the Arrow Lakes Reservoir—see Jackson et al. [1995]), due, in part, to the large number of potentially confounding factors at work (Fenneman and Hawkes). Nevertheless, it can be assumed that tolerance limits are fairly species-specific and are constrained by the life history attributes of the taxon or taxa in question. For example, Naiman and Décamps (1997) grouped riparian plants into four broad categories of functional adaptations:

1) Invaders—produce large numbers of wind- and water-disseminated propagules that colonize alluvial substrates;
2) Endurers—resprout after breakage or burial of either the stem or roots from floods;
3) Resisters—withstand flooding for long periods during the growing season;
4) Avoiders—lack adaptations to prolonged flooding; individuals germinating in an unfavorable habitat do not survive.

Applying this classification to some of the more widely-planted species under CLBWORKS-1 (e.g., Kellogg's sedge, black cottonwood, and Scouler's willow), Kellogg's sedge might qualify as a resister (it has a demonstrated capacity to withstand fluctuating water levels), cottonwood as either an endurer (it can develop adventitious roots from broken branches) or an avoider (it has only a moderate tolerance to anaerobic conditions and a low tolerance to both water stress and exposure to drought) depending on the elevation band and water table proximity, and Scouler's willow as an avoider (it is primarily an upland species not typically found in the drawdown zone).

While coarse, this classification scheme is useful for understanding current drawdown zone plant community development and distributional patterns within the context of reservoir disturbance, and for predicting plant responses to disturbance regimes over the long term. It also offers a possible explanation for the poor performances overall of Scouler's willow and black cottonwood, though not necessarily for that of Kellogg's sedge.

6.2.3. MQ 3: What environmental conditions, including the current operating regime (i.e., timing, frequency, duration and depth of inundation), may limit or improve the remediation and expansion of vegetation communities in the drawdown zone?

Anticipated response, based on preliminary results: "The current operating regime is the most important, though not the only, variable limiting revegetation success in the drawdown zone."

Reservoir drawdown zones provide particularly challenging conditions within which to establish plant communities through revegetation efforts (Nilsson 1981, Abrahams 2006; Liu and Willison 2013). This is due to a combination of factors:

- the prolonged (but not continuous) seasonal inundation of most of the zone;
- the counter-seasonal fluctuation of water levels, in which the reservoir is held at low water during the spring and then the water gradually increases throughout the summer (opposite of the cycle that most plants are adapted to);
- summer moisture-deficits (prior to inundation);
- shoreline freezing during winter drawdown as ice subsides onto the shore;
- the inter-annual variation in the rates and timing of inundation;
- the often extreme rates of erosion and deposition;
- the low nutrient availability in many of the soils due to the removal of the organic soil layer; and
- the abundance of large woody debris that collects in some areas and precludes plant growth or scours existing vegetation (Figure 6-1).

Figure 6-1: Woody debris accumulation zones in Canoe Reach, north Kinbasket Reservoir (photographed in late summer of 2013). Photos © V. Hawkes.

Prevailing conditions in the reservoir may have impacted reclamation success to different degrees and in different ways, depending on the revegetation treatment in question. For example, we observed deciduous stake mortality as a consequence of woody debris accumulation (and its subsequent removal) in upper elevation bands at some sites in the upper elevation band (e.g., Windfall Creek [Fenneman and Hawkes 2012]). In turn, many sedge plug treatments appear to have been lost as a consequence of being completely buried under deposits of sediment transported during the course of inundation. In some areas, seedling plugs have experienced "pedestaling," whereby the substrate around the plug bases erodes away exposing the root wads and killing the plants.

The survival and vigour of transplants of all types was likely compromised by the extreme annual sequence of prolonged summer and winter inundation alternating with severe spring and early summer desiccation. It is quite evident from their widespread distribution in the reservoir that many naturally occurring species such as Kellogg's sedge are able to cope with, and even thrive under, the harsh hydrologic regime of the reservoir once they become naturally established. However, the capacity of transplanted stakes and plugs to adjust to such a regime change may be considerably less, especially if seedlings have not attained sufficient aboveground biomass prior to inundation to adequately uptake the oxygen needed to fuel respiration, or the necessary root structure required to cope with prolonged desiccation (Fenneman and Hawkes 2012).

We believe that revegetation success has been limited by a combination of the operation-related factors listed above, together with the choice of species employed for revegetation and, in some cases, the choice of sites targeted for revegetation. For example, although black cottonwood appears to be well adapted to seasonal water fluctuations and shows a high tolerance for flooding, it has low drought tolerance and hence would typically be used to revegetate sites with a high water table and/or fine sediments with good water holding capacity. During the CLBWORKS-1 program, stakes of this species were routinely planted on well-drained cobble/gravel substrates above the water table, where they may have succumbed to growing season moisture deficits before they could become established.

Another heavily planted species, Scouler's willow (*Salix scouleriana*), is in fact better adapted to upland habitats (forest edges, clearings, roadsides) than to wetlands or areas that are subject to periodic inundation, and thus may not been an appropriate choice for the revegetation program. Species such as Sitka willow (*Salix sitchensis*) or Pacific willow (*S. lucida* ssp. *lasiandra*), which are prevalent within the drawdown zone of Kinbasket Reservoir, would likely have been better sources of willow stakes, and their incorporation into the project may have increased the survivorship of the stakes. Furthermore, the collection of the stakes from roadsides and other upland habitats, rather than from existing populations within the drawdown zone (Keefer et al. 2008), may have reduced the likelihood of collecting stakes from individuals that are more ecologically adapted to reservoir conditions (Fenneman and Hawkes 2012).

A number of environmental and other factors were taken into account during the initial site selection process for CLBWORKS-1 to help ensure that future revegetation attempts would have the maximum likelihood of success (Keefer et al. 2007). Factors that were considered included soil properties (physical, chemical), topographical considerations (slope, etc.), exposure to wave action and erosion/deposition, ease of access, and the availability of nearby plant propagules to aid in revegetation/restoration.

However, one factor that does not appear to have been adequately considered is the magnitude of effect that woody debris accumulation could have on revegetated sites. The damage associated with woody debris scouring and accumulation, compounded by the soil compaction and disturbance associated with subsequent debris removal, has been a major factor limiting revegetation success. Identification of woody debris drift patterns and deposition zones in Kinbasket Reservoir using historical imagery and any other available records should be a key component of site selection and verification in any ongoing reclamation efforts.

6.2.4. MQ 4: What is the relative effectiveness of the different revegetation treatments, as applied through CLBWORKS-1, at increasing the quality and quantity of vegetation in the drawdown zone?

Anticipated response, based on preliminary results: "All are ineffective."

Based on four year of results, only the sedge plug revegetation treatment appears to have achieved any measurable degree of early establishment success, but only in very limited areas. None of the revegetation treatments applied to date have been shown to be effective at increasing the quality and quantity of vegetation in the drawdown zone of Kinbasket Reservoir. Effectiveness assessments have been hampered by the lack of a formal set of performance measures against which to evaluate monitoring results, a failure to formerly define "quality" (as in "quality of vegetation") at the outset, the overall low establishment success of treatments, and small sample sizes along with a lack of replication and stratification in the treatments available for monitoring.

6.2.5. MQ 5: Does implementation of the revegetation program result in greater benefits (e.g., larger vegetated areas, more productive vegetation) than those that could be achieved through natural colonization alone?

Anticipated response, based on preliminary results: "No."

While there has been occasional, moderately successful plug establishment in limited areas, there is little evidence to suggest that the revegetation program has produced anything more than a negligible net benefit with respect to size and productivity of vegetated areas. An analysis of how the establishment rate from the planting program compares with that of natural colonization rates was not part of the present study design. While such an analysis could be informative, it would require new data to be collected.

However, from our monitoring activities within permanent vegetation sites (both for CLBMON-9 and CLBMON-10), we can infer that natural colonization plays an active and ongoing role in structuring local reservoir community dynamics. Individual plants species can occur in a range of sizes and ages on the same microsite, with a high proportion of the local population often consisting of seedling and juvenile stages. Dense carpets of Kellogg's sedge seedlings, in particular, are frequently encountered during surveys.

A number of sites at all elevations, but especially at low and mid elevations, have undergone notable turnovers in species abundance and composition from one sample year to the next. These species turnovers often appear to be precipitated by sediment transport; as sediment becomes deposited on a microsite during flooding, it buries the existing vegetation and creates microsite openings for new colonizers to establish (Hawkes et al. 2010, 2013). Colonization (and re-colonization) presumably occur via a combination of vegetative spread, regeneration of remnant individuals, transported seeds and vegetative propagules, and germination from the soil seed bank (Naiman and Décamps 1997; Jansson et al. 2000), although the relative importance of these different processes in increasing the size of vigour of vegetated areas in the Kinbasket Reservoir drawdown zone is presently unclear. The development of the above-ground vegetation in other temporary wetlands and riparian zones has been ascribed to germination and establishment from the persistent seed bank, and to vegetative propagules that survive drought and flooding (Naiman and Décamps 1997; Casanova and Brock 2000; Capon and Brock 2006; Liu et al. 2006). However, there are few data on the effects of deeper and prolonged inundation on the soil seed and vegetative propagule banks, or how the seasonal timing of inundation of large reservoirs affects sprouting from these sources (Lu et al. 2010).

At the landscape scale, the distribution and extent of vegetation communities in the drawdown zone has remained relatively static since 2007 (Hawkes et al. 2013). At this larger scale, natural colonization events appear infrequent under present operating conditions. This may be because most of the available suitable shoreline is already at least partially established with vegetation cover, leaving uninhabited only those areas that are inherently inimical to plant establishment as a result of either rocky substrates, inadequate soil formation, low nutrient levels, low water-holding capacity, high erodibility, exposure to wave action, steep gradients, or exposure to woody debris scouring and accumulation.

Nevertheless, the potential does exist for some of these areas to become revegetated through natural colonization processes should conditions change, particularly in the case of sites impacted by woody debris.

The original terms of reference for the CLBWORKS-1 program did not consider the potential role that could be filled by natural colonization and regeneration processes, particularly seed bank germination and regeneration of remnant individuals, in helping achieve reclamation objectives. However, we surmise that the soil seed bank (and the supply of vegetative propagules and remnant vegetative fragments) within the drawdown zone may be an important untapped resource (Naiman and Décamps 1997; Lu et al. 2010). For example, anecdotal evidence suggests that the mere act of removing woody debris from an accumulation zone can, in some instances, be sufficient to trigger a rapid rebound in plant cover (V. Hawkes, pers. obs.). We hypothesize that long-standing woody debris accumulations, which form an effective barrier to currents and wave action, may create temporary "safe sites" or settlement areas for plant propagules including floating seeds. Some of the retained seeds become buried in the soil below the logs where they form a persistent seed bank; when the woody cover is removed, the seeds are released from dormancy and germinate. In most situations, recently vacated sites are probably typically reburied by debris before regenerating vegetation has a chance to become fully established.

6.2.6. MQ 6: Is there an opportunity to modify operations to more effectively maintain revegetated communities at the site level in the future?

Anticipated response, based on preliminary results: "Qualified yes."

There is little doubt that the operating regime in place since the commencement of the planting program has had a negative impact on the revegetation success to date. Most transplanted plants have clearly been unable to cope with the combination of inundation timing, frequency, duration and depth, or with the by-products of these factors such as attendant erosion, woody debris scouring, and droughty conditions. Due to the low success rate of revegetation establishment, there is little prospect for community development on revegetated sites and hence little in the sense of "revegetated communities" to maintain in future. In this respect, we anticipate that there will be little opportunity to modify operations to maintain revegetated communities (since there are currently few to maintain).

As a direct consequence of reservoir operations, the Kinbasket Reservoir drawdown zone has experienced a notable decrease in the average number and quality of available growing days since the initiation in 2007 of CLBWORKS-1 (Section 5.6). There are reasons to suspect that the reduced growing times (and increased inundation times) may have negatively impacted the success of remediation efforts, considering the effects observed on natural vegetation (see Hawkes et al. 2010, 2013) and the likelihood that recently transplanted stock has reduced physiological tolerance to flooding (Section 6.2.2). It is fairly clear that from an operational perspective, a more effective way to maintain revegetated communities would be to improve basic environmental conditions for planting treatments. This could be achieved by reducing inundation depth and duration, delaying the timing of inundation to allow for adequate root and stem development, reducing the frequency of full pool events to protect shrub vegetation growing in the upper elevation bands, and making flood events more consistent year-to-year.

7.0 SUMMARY AND RECOMMENDATIONS

It is evident from results of the past two CLBMON-9 assessments (in 2011 and 2013) that revegetation efforts in the Kinbasket Reservoir have not succeeded. Both live stake and seedling plug transplant mortalities have been high in the areas sampled: nearly 100 per cent for live stakes, and up to 96 per cent for plug seedlings. A number of factors likely contribute to the difficulties in plant establishment, some of which may be remedied by changes in planting protocol, while others are directly linked to the reservoir operating regime. Results of field surveys conducted in 2011 and 2013 showed no statistically significant differences in community structure between treated and control sites anywhere in the reservoir. This suggests that current revegetation practices may not be sufficient to meet some of the broader revegetation goals (e.g., increase the areal extent and diversity of vegetation in the drawdown zone, improve wildlife habitat in the drawdown zone, increase productivity of the drawdown zone).

As of 2013, we have succeeded in answering some, though not all, of the original management questions:

- The revegetation treatments applied during the initial four years of CLBWORKS-1 have a low likelihood of meeting the program objectives.
- While all treatment types fared poorly, seedling plugs (of both graminoid and deciduous species) seem to outperform live stakes (although higher success rates for staking could likely be achieved with a different selection of species).
- The current operating regime (i.e., timing, frequency, duration, and depth of inundation) and various attendant factors (e.g., erosion, sedimentation, woody debris accumulation and scouring) limit the remediation and expansion of vegetation communities, as does the choice of locations targeted for revegetation.

Additionally, we can make some predictions about which conditions will actually improve remediation and expansion of vegetation communities: From an operational perspective, this includes increasing the number and quality of available growing days by reducing inundation depth and duration, adjusting the timing of inundation to better mimic natural flood regimes, and reducing the frequency of full pool events to protect woody vegetation growing in the upper elevation bands.

We do not yet know whether implementation of the revegetation program yields greater benefits than those that could be achieved through natural colonization and regeneration processes alone, although we suspect that the answer is “No.” Opportunities may exist for facilitating these latter processes that could potentially yield greater benefits than the current planting program.

7.1. Recommendations

We provide the following recommendations for improving the success of the program in future years. Several recommendations are carried over from the previous implementation year (Fenneman and Hawkes 2012) and are intended to improve the survivorship of planted stakes and seedlings and ensure better monitoring through both the CLBWORKS-1 and CLBMON-9 monitoring programs. New recommendations are also provided for pursuing physical works alternatives to planting as way of meeting reclamation objectives.

1) **Integrate data collection schedules for CLBMON-9 and -10 and modify the scope of work for CLBMON-9 so that the primary focus is on effectiveness monitoring.**
    - The current scope of work for CLBMON-9 overlaps in places with that of CLBMON-10. For example, both studies employ similar data collection protocols for sampling existing vegetation. Although CLBMON-10 is referred to as a landscape-scale study, vegetation mapping is done at the 1:5,000 scale, which is consistent with a site-scale study. Much of the information needed to address the CLBMON-9 management questions pertaining to changes in existing vegetation could be obtained, with minor work scope modifications, through the CLBMON-10 program. Integrating the sampling schedule of CLBMON-9 with that of -10 such that all aspects of existing vegetation (site and landscape) are considered on the same schedule would lead to financial efficiencies for BC Hydro while retaining the scope of work for both CLBMON-9 and -10. This would also help ensure that the primary focus of the CLBMON-9 program remains on revegetation effectiveness monitoring.
2) **Improve integration of the CLBWORKS-1 and CLBMON-9 programs so that revegetation efforts under CLBWORKS-1 occur in better conjunction with the monitoring study design.**
    - During past seasons, lack of communication between the revegetation program (CLBWORKS-1) and the revegetation monitoring program (CLBMON-9) have resulted in some inefficiencies in the monitoring study. Going forward, increased communication between these efforts is recommended so that the monitoring program can be kept up-to-date with the status of the planting program, and vice versa.
    - If revegetation treatments are applied in the drawdown zone of Kinbasket Reservoir in future years, monitoring of those communities under CLBMON-9 should occur in the same year. This may entail modifying the proposed schedule for CLBMON-9.
3) **Clarify long-term goals and interim project benchmarks to better track the progress of the planting program.**
    - Well-defined project benchmarks and long-term goals, such as survivorship rates or number of hectares of established vegetation, would allow the revegetation program to gauge its success in quantitative measures. The specific targets selected would be based on consultation with both the revegetation contractor and representatives of BC Hydro.

- Planting prescriptions should be developed at the outset with clearly articulated goals and objectives. If it appears that performance measures are not being met, prescriptions should be revised using an adaptive management approach (Walters 1986).

4) **Use knowledge of reservoir fetch to exclude sites from the planting program that are subject to excessive erosion, deposition, or woody debris accumulation. Focus future planting efforts on sites with demonstrated capability to support revegetation and on augmenting natural regeneration sites.**

   - The success of revegetation efforts has been hampered in some areas due to unanticipated erosion and deposition as well as accumulation of woody debris over the revegetation polygons. For example, a revegetation treatment at Windfall Creek was lost entirely in 2011 as a result of woody debris accumulation and the disturbance associated with its subsequent removal. Although a certain level of uncertainty regarding such events may be unavoidable, all efforts should be made to identify fetch (wind and wave patterns) in the reservoir so that sites with high exposure can be excluded from revegetation. For example, Hawkes et al. (2013) assessed fetch in Kinbasket Reservoir and used that information to assess why species richness and diversity increased in certain vegetation communities. Fetch data could also be used to identify those areas of the drawdown zone that are prone to woody debris accumulation (Hawkes et al. 2013). BC Hydro also knows where the historical woody debris accumulation sites are located. As Keefer et al. (2011) point out, information regarding woody debris accumulation sites and/or removal plans for a given year should be obtained during the planning phase (i.e., prior to applying the revegetation treatments).
   - Transplants of nursery and other stock, such as have been undertaken through CLBWORKS-1, can continue to be a part of an overall revegetation program if budgets permit. However, prescriptions should be specifically developed for areas of the drawdown zone where plants are likely to grow (e.g., Adama 2013). This might include currently vegetated sites, protected bays, seepage areas, wet depressions, areas with abundant topographic featuring, soil accumulation zones, areas protected from sediment loading, and areas free of woody debris scouring. Appropriate species selection is also critical, and species assemblages should be selected both with functional adaptations in mind and with consideration for the specific conditions prevailing at the receiving sites (Fenneman and Hawkes 2012). In 2013, such an approach was followed in stocking 3.3 ha of drawdown zone habitat at Bear Island (Bush Arm) with sedge seedling plugs (Kellogg's sedge and Columbia sedge; Adama 2013).
   - Future emphasis of the planting program should be on facilitating existing colonization processes rather than on initiating new ones. If recommendation 6 (below) is implemented, we recommend concentrating augmentation treatments on sites where woody debris clearing has shown a capacity for increasing natural regeneration success. Augmentation prescriptions should be developed for in-fill planting of complementary species directly within these sites.

5) **Implement controlled, experimental planting trials such as those recommended in the terms of reference for CLBMON-35.**

   - Due to a high number of potentially confounding factors, current data are inadequate for accurately characterizing species-specific responses to inundation timing, frequency, duration and depth (Management Question #2). Carefully-controlled, replicated planting trials, involving a variety of different species and habitat conditions, are needed to determine the optimal species/methods for revegetation that will yield maximum success given current operating conditions. The TOR for CLBMON-35, which provide the precedent for undertaking such an investigation within the context of revegetating Arrow Lakes Reservoir, could serve as the model for a similar study in the Kinbasket Reservoir.

6) **Explore the potential of woody debris removal for facilitating natural colonization and/or regeneration processes.**

   - The original terms of reference for CLBWORKS-1 did not consider the potential role that could be filled by natural colonization and regeneration processes, particularly seed bank germination and regeneration of remnant individuals, in helping achieve reclamation objectives. Based on revegetation results to date, we believe that facilitating natural colonization processes through targeted physical works may be a more efficient approach than site stocking for achieving vegetation remediation objectives in the long term.
   - Anecdotal evidence suggests that reducing woody debris accumulation on sites with dormant seed and/or rhizome banks can stimulate rapid regrowth, possibly providing a more cost-effective route to site remediation over the long term than site stocking. In lieu of more costly physical works, we recommend that woody debris be removed from selected sites in the drawdown zone, and that CLBMON-9 evaluate the effectiveness of targeted woody debris removal in enhancing colonization and regeneration processes.
   - Because a reservoir-wide woody debris management program, CLBWORKS-16, is already in place on the Kinbasket Reservoir, it would be a relatively simple and inexpensive matter to redirect some of the resources for this program onto clearing debris from sites that demonstrate strong potential for natural regeneration. A profile of regeneration potentials for sites around the reservoir could be developed using woody debris accumulation data (to identify areas of high, moderate, low, and nil accumulation), soil seed bank profiles, soil fertility assays, evidence of nascent vegetation establishment (as indicated by seedling crops), and recent land use history. A study design together with treatment (debris removal) prescriptions could then be developed for target sites, including the identification of suitable control sites, which would allow for formal effectiveness monitoring.

7) **Consider alterations to reservoir operations that would create more predictable, more stable, and less detrimental flooding regimes.**

   - Alterations to the current flooding regime, such as reducing inundation depth and duration, delaying the timing of inundation to allow for adequate root and stem development, reducing the frequency of full pool events to protect shrub vegetation growing in the upper elevation bands, and making flood events more consistent year-to-year, would help promote natural revegetation within the drawdown zone. The current operating regime creates a cyclical pattern that perpetuates the appearance of pioneering species in the drawdown zone while limiting the establishment and development of vegetation communities through natural ingress or via revegetation efforts. Altering the flooding regime would likely have a much larger and more widespread impact on the distribution of vegetation in the reservoir than the current revegetation program because it would impact all areas of the reservoir simultaneously.

8.0 REFERENCES

Abrahams, C. 2005. The ecology and management of drawdown zones. British Wildlife 16:395–402.

Abrahams, C. 2006. Sustainable shorelines: the management and revegetation of drawdown zones. Journal of Practical Ecology and Conservation 6:37–51.

Adama, D. 2013. Kinbasket and Arrow Lakes Reservoir Revegetation Management Plan. CLBWORKS-01: Kinbasket Revegetation 2013. Phase 1 Progress Report. Unpublished report by LGL Limited environmental research associates, Sidney, B.C., for BC Hydro Generations, Water Licence Requirements, Burnaby, B.C. 8 pp.

Allen, H.H., and C.V. Klimas. 1986. Reservoir shoreline revegetation guidelines. Technical Report E-86-13, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS., NTIS No. AD A175 368.

BC Hydro. 1983. Keenleyside Power Plant Project – Review of Design Flood Criteria, Hydroelectric Engineering Division Report No. H1497, March 1983

BC Hydro. 2005. Consultative Committee Report: Columbia River Water Use Plan, Volumes 1 and 2. Report prepared for the Columbia River Water Use Plan Consultative Committee by BC Hydro, Burnaby, B.C. 924 pp.

BC Hydro. 2007. Columbia River Project Water Use Plan. BC Hydro Generation, Burnaby B.C. 41 pp.

BC Hydro. 2008. Monitoring Program No. CLBMON-9. Kinbasket Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis. Contract Q8-7956. Advertisement for Proposals. 197 pp.

Bonham, C.D. 1989. Measurements for Terrestrial Vegetation. John Wiley and Sons. New York. 338 pp.

Capon, S.J., and M.A. Brock. 2006. Flooding, soil seed bank dynamics and vegetation resilience of a hydrologically variable desert floodplain. Freshwater Biology 51(2):206–223.

Casanova, M.T., and M.A. Brock. 2000. How do depth, duration and frequency of flooding influence the establishment of wetland plant communities? Plant Ecology 147:237–250.

Douglas, G.W., D.V. Meidinger, and J. Pojar (editors). 2001a. Illustrated Flora of British Columbia, Volume 6: Monocotyledons (Acoraceae through Najadaceae). B.C. Ministry of Environment, Lands and Parks and B.C. Ministry of Forests. Victoria. 361 pp.

Douglas, G.W., D.V. Meidinger, and J. Pojar (editors). 2001b. Illustrated Flora of British Columbia, Volume 7: Monocotyledons (Orchidaceae through Zosteraceae). B.C. Ministry of Sustainable Resource Management and B.C. Ministry of Forests. Victoria. 379 pp.

Douglas, G.W., D.V. Meidinger, and J. Pojar (editors). 2002. Illustrated Flora of British Columbia, Volume 8: General Summary, Maps and Keys. B.C. Ministry of Sustainable Resource Management and B.C. Ministry of Forests. Victoria. 457 pp.

Douglas, G.W., D.V. Meidinger, and J. Pojar (editors). 1999a. Illustrated Flora of British Columbia. Volume 3: Dicotyledons (Diapensiaceae through Onagraceae). B.C.

Ministry of Environment, Lands & Parks and B.C. Ministry of Forests. Victoria. 423 pp.

Douglas, G.W., D.V. Meidinger, and J. Pojar (editors). 1999b. Illustrated Flora of British Columbia. Volume 4: Dicotyledons (Orobanchaceae through Rubiaceae). B.C. Ministry of Environment, Lands & Parks and B.C. Ministry of Forests. Victoria. 427 pp.

Douglas, G.W., D.V. Meidinger, and J. Pojar (editors). 2000. Illustrated Flora of British Columbia. Volume 5: Dicotyledons (Salicaceae through Zygophyllaceae) and Pteridophytes. B.C. Ministry of Environment, Lands & Parks and B.C. Ministry of Forests. Victoria. 389 pp.

Douglas, G.W., G.B. Straley, D.V. Meidinger, and J. Pojar (editors). 1998a. Illustrated Flora of British Columbia. Volume 1: Gymnosperms and Dicotyledons (Aceraceae through Asteraceae). B.C. Ministry of Environment, Lands & Parks and B.C. Ministry of Forests. Victoria. 436 pp.

Douglas, G.W., G.B. Straley, D.V. Meidinger, and J. Pojar (editors). 1998b. Illustrated Flora of British Columbia. Volume 2: Dicotyledons (Balsaminaceae through Cucurbitaceae). B.C. Ministry of Environment, Lands & Parks and B.C. Ministry of Forests. Victoria. 401 pp.

Fenneman, J.D., and V.C. Hawkes. 2012. CLBMON-9 Kinbasket Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis. Annual Report – 2011. LGL Report EA3271. Unpublished report by LGL Limited, Sidney, B.C., for BC Hydro Generation, Water Licence Requirements, Castlegar, B.C. 78 pp. + Appendices.

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

Hawkes, V.C., and P.T. Gregory. 2012. Temporal changes in the relative abundance of amphibians relative to riparian buffer width in western Washington, USA. Forest Ecology and Management 274:67–80.

Hawkes, V.C., and J.E. Muir. 2008. CLBMON-10 Kinbasket Reservoir Inventory of Vegetation Resources. Annual Report – 2008. LGL Report EA1986. Unpublished report by LGL Limited environmental research associates, Sidney, B.C., for BC Hydro Generation, Water License Requirements, Castlegar, B.C. 62 pp.

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

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

Hawkes, V.C., P. Gibeau, and J.D. Fenneman. 2010. CLBMON-10 Kinbasket Reservoir Inventory of Vegetation Resources. Annual Report – 2010. LGL Report EA3194. Unpublished report by LGL Limited environmental research associates, Sidney, B.C., for BC Hydro Generations, Water License Requirements, Castlegar, B.C. 92 pp. + Appendices.

Hill, N.M., P.A. Keddy, and I.C. Wisheu 1998. A hydrological model for predicting the effects of dams on the shoreline vegetation of lakes and reservoirs. Environmental Management 22:773–736.

Jackson, J.L., K. Hennebury, and D. Baker. 1995. Reclaiming reservoirs—native species revegetation of shorelines. Proceedings of the 19th Annual British Columbia Mine Reclamation Symposium. Unpublished report. BC Hydro, Corporate Safety and Environment and University of Northern British Columbia, Faculty of Natural Resources and Environmental Studies. 13 pp.

Jansson, R., C. Nilsson, M. Hynesius, and E. Andersson. 2000. Effects of river regulation on river-margin vegetation: a comparison of eight boreal rivers. Ecological Applications 10(1):203–224.

Johansson, M.E., and C. Nilsson. 2002. Responses of riparian plants to flooding in free-flowing and regulated boreal rivers: an experimental study. Journal of Applied Ecology 39:971–986.

Johnson, W.C. 2002. Riparian vegetation diversity along regulated rivers: contribution of novel and relict habitats. Freshwater Biology 47:749–759.

Junk, W.J., P.B. Bayley, and R.E. Sparks. 1989. The flood pulse concept in river-floodplain systems. Canadian Special Publication Fisheries and Aquatic Sciences 106:110–127.

Keefer, M.E., T.J. Ross, T. Ehlers, and J. Meuleman. 2008. CLBWORKS-1 Kinbasket Reservoir Revegetation Program Physical Works Report (2008). Report prepared by Keefer Ecological Services for BC Hydro. 53 pp. + Appendices.

Keefer, M.E., R. Moody, K. Dixon, and A. Kennedy. 2011. Kinbasket Reservoir Revegetation Program Physical Works Report (2010). Report prepared by Keefer Ecological Services for BC Hydro. 41 pp. + Appendices.

Keefer, M.E., R. Moody, T.J. Ross, A. Chapman, and J. Meuleman. 2010. Kinbasket Reservoir Revegetation Program Physical Works Report (2009). Report prepared by Keefer Ecological Services for BC Hydro. 39 pp. + Appendices.

Keefer, M.E., T.J. Ross, and K. Kettenring. 2007. Kinbasket Reservoir Revegetation Program Physical Works (Phase 1) Site Verification and Seed Collection. Report prepared by Keefer Ecological Services for BC Hydro. 21 pp. + Appendices.

Legendre, P. 2005. Species associations: the Kendall coefficient of concordance revisited. Journal of Agricultural, Biological and Environmental Statistics 10:226–245.

Legendre, P., and E. Gallagher. 2001. Ecologically meaningful transformations for ordination of species data. Oecologia 129:271–280.

Legendre, P., and L. Legendre. 1998. Numerical Ecology, Developments in Environmental Modelling, Second English Edition. Elsevier, Amsterdam. 853 pp.

Liu, G.H., W. Li, J. Zhou, W.Z. Liu, D. Yang, and A.J. Davy. 2006. How does the propagule bank contribute to cyclic vegetation change in a lakeshore marsh with seasonal drawdown? Aquatic Botany 84(2):137–143.

Liu, Y., and J.H. Willison. 2013. Prospects for cultivating white mulberry (*Morus alba*) in the drawdown zone of the Three Gorges Reservoir, China. Environmental Science and Pollution Research International 20:7142–7151.

Lu, Z.J., L.F. Li, M.X. Jiang, H.D. Huang, and D.C. Bao. 2010. Can the soil seed bank contribute to revegetation of the drawdown zone in the Three Gorges Reservoir Region? Plant Ecology 209:153–165.

Luttmerding, H.A., D.A. Demarchi, E.C. Lea, D.V. Meidinger, and T. Vold. 1998. Field manual for describing terrestrial ecosystems. Land Management Handbook Number 25. B.C. Ministry of Environment, Lands and Parks and BC Ministry of Forests, Victoria, B.C.

Machmer, M., and C. Steeger. 2002. Effectiveness monitoring guidelines for ecosystem restoration. B.C. Ministry of Environment, Victoria, B.C. 18 pp.

MacKillop, S. 2003. Investigations of revegetation strategies using woody species for fish habitat enhancement and aesthetic improvement in the drawdown zone at Buttle Lake, British Columbia. M.Sc. thesis, Royal Roads University, Victoria, B.C. 102 pp.

Marcot, B.G. 1998. Selecting appropriate statistical procedures and asking the right questions: a synthesis. *In* Statistical methods for adaptive management. V. Sit and B. Taylor (eds.). Land Management Handbook No. 42. Research Branch, B.C. Ministry of Forests, Victoria, B.C.

Massart, D.L., J. Smeyers-Verbeke, X. Capron, and K. Schlesier. 2005. Visual presentation of data by means of box plots. LCGC Europe 18(4):215–218.

Moody, A., and W. Carr. 2003. Mica-Revelstoke-Keenleyside Water Use Plan: potential areas for vegetation establishment in Kinbasket Reservoir. BC Hydro Contract Report.

Mueller-Dombois, D., and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, New York. 547 pp.

Naiman, R.J., and H. Décamps. 1997. The ecology of interfaces: riparian zones. Annual Review of Ecology and Systematics. 28: 621–658.

New T., and Z. Xie. 2008. Impacts of large dams on riparian vegetation: applying global experiences to the case of China's Three Gorges Dam. Biodiversity Conservation17: 3149–3163.

Nilsson, C. 1981. Dynamics of the shore vegetation of a North Swedish hydro-electric reservoir during a 5-year period. Acta Phytogeogr. Suec. 69. Uppsala.

Nilsson, C., and K. Berggren. 2000. Alterations of riparian ecosystems caused by river regulation. BioScience 50(9): 783–792.

Nilsson, C., and M. Svedmark. 2002. Basic principles and ecological consequences of changing water regimes: riparian plant communities. Environmental Management 30(4):468–480.

Noon, B.R. 2003. Conceptual issues in monitoring ecological resources. In: D.E. Busch, and J.C. Trexler, editors. Monitoring Ecosystems: Interdisciplinary Approaches for Evaluating Ecoregional Initiatives. Island Press, Washington, D.C.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The natural flow regime. BioScience 47:769–984.

Shumar, M.L., and J.E. Anderson. 1987. Transplanting wildings in small revegetation projects. Arid Soil Research and Rehabilitation 1:253–256.

Sokal, R.R., and F.J. Rohlf. 1995. Biometry: the principles and practices of statistics in biological research. 3rd edition. New York. 887 pp.

USDA-NRCS. 1997. National Grazing Lands Handbook. USDA-NRCS, Washington, D.C.

Walters, C.J. 1986. Adaptive management of renewable resources. McMillan, New York.

WCD 2000. Dams and Development: The Report of the World Commission on Dams. Earthscan Publications Ltd., London. 404 pp.

Western States Laboratory Proficiency Testing Program. 1997. Soil and Plant Analytical Methods. Version 4.00.

Wu, J., J. Huang, X. Han, X. Gao, F. He, M. Jiang, Z. Jiang, R.B. Primack, and Z. Shen. 2004. The Three Gorges Dam: an ecological perspective. Frontiers in Ecology and the Environment 2(5):241–248.

Yang, F., W.-W. Liu, J. Wang, L. Liao, and Y. Wang. 2012. Riparian vegetation's responses to the new hydrological regimes from the Three Gorges Project: clues to revegetation in reservoir water-level-fluctuation zone. Acta Ecologica Sinica 32(2012):89–98.

Yazvenko, S.B. 2009. CLBMON-9 Kinbasket Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis. Sampling Design. Prepared for BC Hydro by LGL Limited, Sidney, B.C. 19 pp. + Appendices.

Yazvenko, S.B., V.C. Hawkes, and P. Gibeau. 2010. CLBMON-9 Kinbasket Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis. Annual Report – 2009. LGL Report EA3073. Unpublished report by LGL Limited, Sidney, B.C., for BC Hydro Generation, Water Licence Requirements, Castlegar, B.C. 83 pp. + Appendices.

9.0 APPENDICES

Appendix 9-A: Vegetation species documented from plots in the drawdown zone of Kinbasket Reservoir (739–754 m ASL) sampled during 2013 field work

Species Code	Common Name	Scientific Name
ACHIMIL	common yarrow	*Achillea millefolium*
ACHIALP	Siberian yarrow	*Achillea alpina*
AGROCAP	colonial bentgrass	*Agrostis capillaris*
AGROEXA	spike bentgrass	*Agrostis exarata*
AGROGIG	redtop	*Agrostis gigantea*
AGROSCA	hair bentgrass	*Agrostis scabra*
ALNUINC	mountain alder	*Alnus incana ssp. tenuifolia*
ALOPAEQ	little meadow-foxtail	*Alopecurus aequalis*
ANAPMAR	pearly everlasting	*Anaphalis margaritacea*
ANTEANA	showy pussytoes	*Antennaria anaphaloides*
ARENSER	thyme-leaved sandwort	*Arenaria serpyllifolia*
ASTECIL	Lindley's aster	*Symphyotrichum ciliolatum*
BETUPAP	paper birch	*Betula papyrifera*
BIDECER	nodding beggarticks	*Bidens cernua*
BRAYHUM	dwarf braya	*Braya humilis*
CALACAN	bluejoint reedgrass	*Calamagrostis canadensis*
CALASTR	slimstem reedgrass	*Calamagrostis stricta*
CALLPAL	spring water-starwort	*Callitriche palustris*
CALLPAU	spring water-starwort	*Callitriche palustris*
CAPSBUR	shepherd's purse	*Capsella bursa-pastoris*
CARDPEN	Pennsylvanian bitter-cress	*Cardamine pensylvanica*
CAREAPE	Columbia sedge	*Carex aperta*
CAREAQU	water sedge	*Carex aquatilis*
CAREAUR	golden sedge	*Carex aurea*
CAREBEB	Bebb's sedge	*Carex bebbii*
CARECAN	grey sedge	*Carex canescens*
CARECHO	cordroot sedge	*Carex chordorrhiza*
CARECOI	low northern sedge	*Carex concinna*
CARECRA	Crawford's sedge	*Carex crawfordii*
CAREFLA	yellow sedge	*Carex flava*
CAREGAR	Garber's sedge	*Carex garberi*
CAREINT	inland sedge	*Carex interior*
CARELAS	slender sedge	*Carex lasiocarpa ssp. americana*
CARELEN	Kellogg's sedge	*Carex lenticularis var. lipocarpa*
CAREPAC	thick-headed sedge	*Carex pachystachya*
CARESAX	russet sedge	*Carex saxatilis*
CARESIT	Sitka sedge	*Carex sitchensis*
CARESTI	awl-fruited sedge	*Carex stipata*
CAREUTR	beaked sedge	*Carex utriculata*
CAREVIR	green sedge	*Carex viridula*
CASTMIN	scarlet paintbrush	*Castilleja miniata*
CERAFON	mouse-ear chickweed	*Cerastium fontanum*
CHENALB	lamb's-quarters	*Chenopodium album*
CICUDOU	Douglas' water-hemlock	*Cicuta douglasii*
CIRCALP	enchanter's-nightshade	*Circaea alpina*

Species Code	Common Name	Scientific Name
CIRSVUL	bull thistle	*Cirsium vulgare*
CLIMDEN	tree climacium moss	*Climacium dendroides*
COLLLIN	narrow-leaved collomia	*Collomia linearis*
COMAPAL	marsh cinquefoil	*Comarum palustre*
COMAPAU	marsh cinquefoil	*Comarum palustre*
CONYCAN	horseweed	*Conyza canadensis*
CORNCAN	bunchberry	*Cornus canadensis*
CORNSTO	red-osier dogwood	*Cornus stolonifera*
CORYAUR	golden corydalis	*Corydalis aurea*
CREPELE	elegant hawksbeard	*Crepis elegans*
CREPTEC	annual hawksbeard	*Crepis tectorum*
DANTSPI	poverty oatgrass	*Danthonia spicata*
DESCCES	tufted hairgrass	*Deschampsia cespitosa*
DESCDAN	annual hairgrass	*Deschampsia danthonioides*
DESCELO	slender hairgrass	*Deschampsia elongata*
DESCSOP	flixweed	*Descurainia sophia*
DICHACU	western witchgrass	*Dichanthelium acuminatum*
DIGIPUR	common foxglove	*Digitalis purpurea*
DROSANG	great sundew	*Drosera anglica*
DROSROT	round-leaved sundew	*Drosera rotundifolia*
DRYADRU	yellow mountain-avens	*Dryas drummondii*
ELEOELL	slender spike-rush	*Eleocharis elliptica*
ELEOMAM	nipple spike-rush	*Eleocharis mamillata*
ELEOPAL	common spike-rush	*Eleocharis palustris*
ELYMGLA	blue wildrye	*Elymus glaucus*
ELYMLAN	thickspike wildrye	*Elymus lanceolatus*
ELYMREP	quackgrass	*Elymus repens*
EPILANG	fireweed	*Epilobium angustifolium*
EPILBRA	tall annual willowherb	*Epilobium brachycarpum*
EPILCIL	purple-leaved willowherb	*Epilobium ciliatum*
EPILLAT	broad-leaved willowherb	*Epilobium latifolium*
EPILLEP	narrow-leaved willowherb	*Epilobium leptophyllum*
EPILPAL	swamp willowherb	*Epilobium palustre*
EQUIARV	common horsetail	*Equisetum arvense*
EQUIFLU	swamp horsetail	*Equisetum fluviatile*
EQUIPAL	marsh horsetail	*Equisetum palustre*
EQUIPRA	meadow horsetail	*Equisetum pratense*
EQUIVAR	northern scouring-rush	*Equisetum variegatum*
ERAGMEX	Orcutt's lovegrass	*Eragrostis mexicana ssp. virescens*
ERIGPHI	Philadelphia fleabane	*Erigeron philadelphicus*
ERIOVIR	green-keeled cotton-grass	*Eriophorum viridicarinatum*
ERUCGAL	dog mustard	*Erucastrum gallicum*
ERYSCHE	wormseed mustard	*Erysimum cheiranthoides*
EUPHNEM	eastern eyebright	*Euphrasia nemorosa*
EUTHGRA	fragrant goldenrod	*Euthamia graminifolia*
FESTRUB	red fescue	*Festuca rubra ssp. rubra*
FRAGVIR	wild strawberry	*Fragaria virginiana*
GALETET	hemp-nettle	*Galeopsis tetrahit*
GALITRD	small bedstraw	*Galium trifidum*

Species Code	Common Name	Scientific Name
GALITRIFI	small bedstraw	*Galium trifidum*
GEUMMAC	large-leaved avens	*Geum macrophyllum*
GLYCSTR	fowl mannagrass	*Glyceria striata*
GNAPULI	marsh cudweed	*Gnaphalium uliginosum*
HIERCAE	yellow king devil	*Hieracium caespitosum*
HIERHIR	common sweetgrass	*Hierochloe hirta*
HIERPIL	mouse-ear hawkweed	*Hieracium pilosella*
HIPPVUL	common mare's-tail	*Hippuris vulgaris*
HORDJUB	foxtail barley	*Hordeum jubatum*
IMPANOL	common touch-me-not	*Impatiens noli-tangere*
JUNCALP	alpine rush	*Juncus alpinoarticulatus*
JUNCBUF	toad rush	*Juncus bufonius*
JUNCFIL	thread rush	*Juncus filiformis*
JUNCNOD	tuberous rush	*Juncus nodosus*
JUNCTEN	slender rush	*Juncus tenuis*
LEPIDEN	prairie pepper-grass	*Lepidium densiflorum*
LEUCVUL	oxeye daisy	*Leucanthemum vulgare*
LILIPHI	wood lily	*Lilium philadelphicum var. andinum*
LOBEKAL	Kalm's lobelia	*Lobelia kalmii*
LONIINV	black twinberry	*Lonicera involucrata*
LOTUCOR	birds-foot trefoil	*Lotus corniculatus*
LYCOAME	cut-leaved water horehound	*Lycopus americanus*
LYCOUNI	northern water horehound	*Lycopus uniflorus*
LYSITHY	tufted loosestrife	*Lysimachia thyrsiflora*
MAIASTE	star-flowered false Solomon's seal	*Maianthemum stellatum*
MARCPOL	green-tongue liverwort	*Marchantia polymorpha*
MATRDIS	pineapple weed	*Matricaria discoidea*
MEDILUP	black medic	*Medicago lupulina*
MEDISAT	alfalfa	*Medicago sativa*
MELIALB	white sweet-clover	*Melilotus alba*
MENTARV	field mint	*Mentha arvensis*
MENYTRI	buckbean	*Menyanthes trifoliata*
MIMUBRV	short-flowered monkey-flower	*Mimulus breviflorus*
MIMUGUT	yellow monkey-flower	*Mimulus guttatus*
MINURUB	boreal sandwort	*Minuartia rubella*
MOSS sp.		
MYOSLAX	small-flowered forget-me-not	*Myosotis laxa*
MYOSSCO	European forget-me-not	*Myosotis scorpioides*
MYRIGAL	sweet gale	*Myrica gale*
PACKPAC	rayless alpine butterweed	*Packera pauciflora*
PACKPAP	Canadian butterweed	*Packera paupercula*
PACKPLA	plains butterweed	*Packera plattensis*
PARNPAR	small-flowered grass-of-Parnassus	*Parnassia parviflora*
PERSAMP	water smartweed	*Persicaria amphibia var. emersa*
PERSMAC	lady's-thumb	*Persicaria maculosa*
PHALARU	reed canarygrass	*Phalaris arundinacea*
PHLEPRA	common timothy	*Phleum pratense*
PICEGLA	white spruce	*Picea glauca*
PLAGSCO	Scouler's popcornflower	*Plagiobothrys scouleri*

Species Code	Common Name	Scientific Name
PLANMAJ	common plantain	*Plantago major*
PLATAQU	northern green rein orchid	*Platanthera aquilonis*
PLATDIL	fragrant white rein orchid	*Platanthera dilatata*
POA COM	Canada bluegrass	*Poa compressa*
POA PAL	fowl bluegrass	*Poa palustris*
POA PRA	Kentucky bluegrass	*Poa pratensis*
POLYAVI	common knotweed	*Polygonum aviculare*
POPUBAL	black cottonwood	*Populus balsamifera ssp. trichocarpa*
POPUTRE	trembling aspen	*Populus tremuloides*
POTEANS	common silverweed	*Potentilla anserina*
POTENOR	Norwegian cinquefoil	*Potentilla norvegica*
PRUNVUL	self-heal	*Prunella vulgaris*
PYROASA	pink wintergreen	*Pyrola asarifolia*
PYROMIN	lesser wintergreen	*Pyrola minor*
RANUACR	meadow buttercup	*Ranunculus acris*
RANUMAC	Macoun's buttercup	*Ranunculus macounii*
RANUPEN	Pennsylvania buttercup	*Ranunculus pensylvanicus*
RANUREP	creeping buttercup	*Ranunculus repens*
RANUSCE	celery-leaved buttercup	*Ranunculus sceleratus var. multifidus*
RHINMIN	yellow rattle	*Rhinanthus minor*
RICCCAV	cavernous crystalwort	*Riccia cavernosa*
RORIPAL	marsh yellow cress	*Rorippa palustris*
ROSAACI	prickly rose	*Rosa acicularis*
ROSAWOO	prairie rose	*Rosa woodsii ssp. ultramontana*
RUBUARC	nagoonberry	*Rubus arcticus ssp. acaulis*
RUBUIDA	red raspberry	*Rubus idaeus ssp. strigosus*
RUBUPUB	dwarf red raspberry	*Rubus pubescens var. pubescens*
RUMEACT	sheep sorrel	*Rumex acetosella*
RUMECRI	curled dock	*Rumex crispus*
SALIBAC	Barclay's willow	*Salix barclayi*
SALIBAR	Barclay's willow	*Salix barclayi*
SALIBEB	Bebb's willow	*Salix bebbiana*
SALIBRA	short-fruited willow	*Salix brachycarpa*
SALICOM	under-green willow	*Salix commutata*
SALIFAR	Farr's willow	*Salix farriae*
SALILUC	Pacific willow	*Salix lucida*
SALIMEL	dusky willow	*Salix melanopsis*
SALIPED	bog willow	*Salix pedicellaris*
SALIPLA	plane-leaved willow	*Salix planifolia*
SALIPRO	Mackenzie willow	*Salix prolixa*
SALIPSD	tall blueberry willow	*Salix pseudomyrsinites*
SALISIT	Sitka willow	*Salix sitchensis*
SALIX sp.		*Salix sp.*
SCIRATR	wool-grass	*Scirpus atrocinctus*
SCIRMIC	small-flowered bulrush	*Scirpus microcarpus*
SCUTGAL	marsh skullcap	*Scutellaria galericulata*
Seedling		
SELASEL	mountain-moss	*Selaginella selaginoides*
SIUMSUA	hemlock water-parsnip	*Sium suave*

Species Code	Common Name	Scientific Name
SOLILEP	Canada goldenrod	*Solidago lepida*
SPERRUB	red sand-spurry	*Spergularia rubra*
SPHAGNUM sp.		*Sphagnum sp.*
SPIRDOU	hardhack	*Spiraea douglasii*
STELLON	long-leaved starwort	*Stellaria longifolia*
SYMPSUB	Douglas' aster	*Symphyotrichum subspicatum*
TARAOFF	common dandelion	*Taraxacum officinale*
TRIAGLU	sticky false asphodel	*Triantha glutinosa*
TRIFAUR	yellow clover	*Trifolium aureum*
TRIFHYB	alsike clover	*Trifolium hybridum*
TRIFPRA	red clover	*Trifolium pratense*
TRIFREP	white clover	*Trifolium repens*
TRIGMAR	seaside arrow-grass	*Triglochin maritima*
TRIGPAL	marsh arrow-grass	*Triglochin palustris*
TURRGLA	tower mustard	*Turritis glabra*
TYPHLAT	Common cattail	*Typha latifolia*
UTRIINT	flat-leaved bladderwort	*Utricularia intermedia*
UTRIMAC	greater bladderwort	*Utricularia macrorhiza*
UTRIMIN	lesser bladderwort	*Utricularia minor*
VERBTHA	great mullein	*Verbascum thapsus*
VEROBEC	American speedwell	*Veronica beccabunga var. americana*
VEROPER	purslane speedwell	*Veronica peregrina*
VICIAME	American vetch	*Vicia americana*
VIOLADU	early blue violet	*Viola adunca*
VIOLMAC	small white violet	*Viola macloskeyi*
VIOLPAL	marsh violet	*Viola palustris var. palustris*

Appendix 9-B: Plant communities of Kinbasket Reservoir (after Hawkes et al. 2007)

Code	Common Name	Scientific Name	Drainage	Location
LL	Lady's thumb – Lamb's quarter	*Polygonum persicaria – Chenopodium album*	imperfect to moderately well	lowest vegetated elevations
CH	Common Horsetail	*Equisetum arvense*	well	above LL or lower elevation on sandy, well-drained soil
TP	Toad Rush – Pond Water-starwort	*Juncus bufonius – Callitriche stagnalis*	imperfectly	above LL, wet sites
KS	Kellogg's Sedge	*Carex lenticularis* ssp. *lipocarpa*	imperfectly to moderately well	above CH
BR	Bluejoint Reedgrass	*Calamagrostis canadensis*	moderately well	above CH, often above KS
MA	Marsh Cudweed – Annual Hairgrass	*Gnaphalium uliginosum – Deschampsia danthonioides*	imperfectly to moderately well	common in the Bush Arm area
RC	Canary Reedgrass	*Phalaris arundinacea*	imperfectly to moderately well	similar elevation to CO community
CO	Clover – Oxeye Daisy	*Trifolium* spp. *– Leucanthemum vulgare*	well	typical just below shrub line and above KS
CT	Cottonwood – Trifolium	*Populus balsamifera* ssp. *trichocarpa – Trifolium* spp.	imperfectly to well drained	above CO, below MC and LH
MC	Mixed Conifer	*Pinus monticola, Pseudotsuga menziesii, Picea engelmannii x glauca, Tsuga heterophylla, Thuja plicata*	well	above CT along forest edge
LH	Lodgepole Pine – Annual hawks beard	*Pinus contorta – Crepis tectorum*	well to rapid	above CT along forest edge, very dry site
BS	Buckbean – Slender Sedge	*Menyanthes trifoliata – Carex lasiocarpa – Scirpus atrocinctus/microcarpus*	very poor to poor	wetland association
WB	Wool-grass – Pennsylvania Buttercup	*Scirpus atrocinctus – Ranunculus pensylvanicus*	imperfectly to poor	wetland association
SH	Swamp Horsetails	*Equisetum variegatum, E. fluviatile, E. palustre*	poor	wetland association
WS	Willow – Sedge wetland	*Salix – Carex* spp.	very poor to poor	wetland association
DR	Driftwood	Long, linear bands of driftwood, very little vegetation	n/a	whole logs and large pieces of logs without bark
WD	Wood Debris	Thick layers of wood debris, no vegetation	n/a	typically small pieces similar to bark mulch
FO	Forest	Any forested community	varies	above drawdown zone (> 756 m ASL)

Appendix 9-C: Locations and variables of sites sampled in 2013

Site	Elevation (m)	UTM_East	UTM_North	Type	Vegetation Community[9]	Region
97	741.7	454221	5735776	Existing	MA	South
501	751.7	353510	5849685	Existing	KS	North
505	751.6	353518	5849629	Existing	SH	North
510	749.5	353927	5849205	Existing	SH	North
514	753.0	474647	5738996	Existing	DR	South
516	751.6	474475	5738948	Existing	CO	South
518	752.7	474502	5739942	Existing	CO	South
520	752.7	475077	5739182	Existing	CO	South
521	752.4	475215	5739245	Existing	SH	South
522	752.7	475150	5739302	Existing	SH	South
523	752.0	474996	5739346	Existing	SH	South
524	752.9	475085	5739398	Existing	WS	South
532	751.5	471972	5736443	Existing	CH	South
535	750.0	474265	5738770	Existing	KS	South
541	746.3	398437	5773050	Existing	KS	Central
542	751.7	398465	5773072	Existing	CO	Central
543	744.9	400161	5772272	Existing	WB	Central
544	749.7	400237	5772194	Existing	WB	Central
545	749.9	400321	5772182	Existing	WB	Central
546	747.6	399168	5779027	Existing	WB	Central
547	748.9	399205	5779064	Existing	WB	Central
548	747.2	355343	5847996	Existing	CH	North
551	751.2	355159	5846672	Existing	KS	North
552	753.4	354955	5846407	Existing	BR	North
555	753.2	354795	5846808	Existing	BR	North
556	751.4	354570	5847927	Existing	WB	North
558	749.7	354222	5848748	Existing	SH	North
560	753.8	361037	5841967	Existing	CO	North
562	749.4	361007	5841811	Existing	CH	North
564	748.6	361202	5841248	Existing	CH	North
566	746.6	361040	5841467	Existing	CH	North
567	746.4	453341	5736598	Existing	MA	South
602	753.1	353397	5849913	Existing	CO	North
604	751.3	354464	5848109	Existing	WB	North
605	754.4	353436	5850046	Existing	CO	North
607	753.0	354410	5847850	Existing	WS	North
609	749.0	354799	5848259	Existing	TP	North
610	748.5	354598	5848395	Existing	WD	North
633	753.4	354801	5846743	Existing	BS	North
634	753.6	354777	5846624	Existing	BS	North
637	748.5	355840	5846068	Existing	LL	North
640	749.6	354601	5848315	Existing	TP	North

[9] Vegetation Community: SH=Swamp Horsetail; CO=Cottonwood – Oxeye Daisy; MA=Marsh Cudweed –Annual Hairgrass; CH=Common Horsetail; MC=Mixed Conifer; WS=Willow – sedge; TP=Toad Rush – Pond Water-starwort; WD=Woody Debris; KS=Kellogg's Sedge; LL=Lamb's-quarters – Lady's-thumb; CT=Cottonwood – Trifolium; BR=Bluejoint Reedgrass; WB=Wool-grass – Pennsylvania Buttercup; NVEG = non-vegetated.

Site	Elevation (m)	UTM_East	UTM_North	Type	Vegetation Community[9]	Region
642	749.9	354398	5848477	Existing	WD	North
643	752.4	353660	5849981	Existing	LL	North
644	751.6	353745	5849905	Existing	CH	North
651	748.3	358132	5845820	Existing	CH	North
652	747.3	358050	5846039	Existing	CH	North
654	743.5	358068	5846221	Existing	LL	North
674	752.8	355672	5845968	Existing	BR	North
676	753.6	355809	5845755	Existing	WS	North
701	746.7	453131	5735945	Existing	MA	South
702	744.4	460543	5736233	Existing	CH	South
703	746.9	464320	5734931	Existing	TP	South
704	748.8	459887	5736266	Existing	KS	South
705	748.6	460222	5736272	Existing	KS	South
706	747.2	461786	5735474	Existing	WB	South
708	749.3	454551	5736482	Existing	WB	South
709	744.9	453404	5736518	Existing	MA	South
711	743.9	462466	5735431	Existing	KS	South
716	744.4	460027	5736250	Existing	KS	South
719	751.9	474870	5739329	Existing	SH	South
720	742.1	460850	5735946	Existing	TP	South
722	747.2	460436	5736298	Existing	CH	South
725	750.2	460937	5736087	Existing	KS	South
727	745.6	460209	5736238	Existing	LL	South
731	745.5	464382	5734827	Existing	KS	South
734	744.1	460299	5736273	Existing	LL	South
742	748.5	452545	5735131	Existing	BR	South
743	753.4	472298	5736815	Existing	CT	South
746	748.7	453365	5735817	Existing	KS	South
750	742.5	464278	5734879	Existing	CH	South
751	746.7	461051	5735311	Existing	LL	South
754	752.9	461648	5735740	Existing	BR	South
755	747.1	460831	5736079	Existing	KS	South
758	752.9	472372	5736850	Existing	CO	South
759	752.3	474832	5739427	Existing	SH	South
760	748.7	461832	5735533	Existing	SH	South
762	741.9	454715	5735554	Existing	LL	South
767	750.9	472498	5736931	Existing	CH	South
769	746.9	452869	5734965	Existing	CH	South
774	741.5	460821	5736011	Existing	TP	South
775	742.4	462603	5735459	Existing	LL	South
776	750.3	461731	5735587	Existing	SH	South
777	753.8	474667	5740092	Existing	WS	South
779	748.6	461742	5735522	Existing	WB	South
780	753.2	474611	5740073	Existing	WS	South
781	742.4	464256	5734890	Existing	CH	South
783	754.4	474824	5740186	Existing	WS	South
785	743.2	459667	5736332	Existing	KS	South
787	742.8	462168	5735354	Existing	LL	South

Site	Elevation (m)	UTM_East	UTM_North	Type	Vegetation Community[9]	Region
788	748.7	460984	5735290	Existing	BR	South
791	746.8	462155	5735411	Existing	LL	South
796	750.5	461601	5735592	Existing	SH	South
900	745.4	355741	5847090	Existing	TP	North
902	745.8	354952	5848859	Existing	WD	North
903	743.5	358156	5845530	Existing	LL	North
904	744.7	360922	5841733	Existing	CH	North
905	741.6	373311	5828292	Existing	LL	North
906	743.7	373413	5828243	Existing	TP	North
907	744.5	373476	5828314	Existing	KS	North
908	743.8	381803	5810646	Existing	LL	North
909	744.4	381559	5810300	Existing	KS	North
913	742.7	399067	5778974	Existing	TP	Central
914	744.6	399114	5778996	Existing	KS	Central
916	743.0	453575	5736451	Existing	LL	South
2011.01C	746.3	453868	5736574	Control	MA	South
2011.01T	745.4	453832	5736549	Treatment	MA	South
2011.02C	747.0	453719	5736684	Control	WB	South
2011.02T	747.3	453687	5736699	Treatment	MA	South
2011.03C	745.0	472681	5737083	Control	CH	South
2011.03T	746.5	472688	5737030	Treatment	CH	South
2011.04C	750.5	471946	5736580	Control	CH	South
2011.05C	752.6	472430	5736866	Control	CH	South
2011.05T	752.5	472519	5736808	Treatment	CH	South
2011.06T	743.2	360900	5841901	Treatment	CH	North
2011.07C	747.1	360955	5841949	Control	CH	North
2011.07T	749.6	361008	5841800	Treatment	CH	North
2011.08C	746.8	361040	5841459	Control	CH	North
2011.08T	746.8	360969	5841607	Control	CH	North
2011.10T	748.2	354213	5849031	Treatment	SH	North
2011.11C	753.0	361318	5841204	Control	CO	North
2011.11T	753.6	361415	5841122	Treatment	CO	North
2011.12C	750.7	361293	5841149	Control	CH	North
2011.12T	751.7	361364	5841088	Treatment	CH	North
2011.13C	749.6	373547	5827997	Control	CO	North
2011.13T	749.8	373537	5827985	Treatment	CO	North
2011.14C	750.2	373617	5827839	Control	CO	North
2011.14T	752.4	373634	5827943	Treatment	CO	North
2011.15C	744.8	373439	5828184	Control	TP	North
2011.15T	744.7	373418	5828167	Treatment	TP	North
2011.16C	746.9	381817	5810588	Control	KS	North
2011.16T	748.0	381830	5810566	Treatment	KS	North
2011.17C	748.3	382102	5810232	Control	CH	North
2011.17T	748.6	382136	5810172	Treatment	CH	North
2011.18C	750.8	353710	5849599	Control	LL	North
2011.18T	750.9	353749	5849620	Treatment	LL	North
2011.19C	751.3	353684	5849706	Control	LL	North
2011.19T	751.3	353607	5849594	Treatment	LL	North

Site	Elevation (m)	UTM_East	UTM_North	Type	Vegetation Community[9]	Region
2011.20C	750.4	353673	5849540	Control	KS	North
2011.20T	750.8	353650	5849514	Treatment	KS	North
2011.21C	753.2	474382	5738314	Control	CO	South
2011.21T	754.0	474405	5738325	Treatment	DR	South
2011.22C	752.4	474438	5738846	Control	CT	South
2011.22T	752.8	474421	5738725	Treatment	DR	South
2011.23C	746.9	472093	5737049	Control	CH	South
2011.23T	747.0	472138	5737035	Treatment	NVEG	South
2011.24T	741.9	360849	5841867	Treatment	NVEG	North
2011.25C	745.4	453787	5736555	Control	MA	South
2011.25T	745.6	453801	5736572	Treatment	MA	South
2011.27T	747.2	453852	5736671	Treatment	MA	South
2011.28T	747.0	453874	5736643	Treatment	MA	South
2011.29T	747.0	453920	5736625	Treatment	MA	South
2011.30C	746.2	453629	5736637	Control	MA	South
2011.30T	746.2	453651	5736631	Control	MA	South
2011.31C	746.6	453637	5736664	Control	BS	South
2011.31T	746.6	453660	5736657	Treatment	MA	South
2011.32C	747.8	453714	5736744	Control	WB	South
2011.32T	747.7	453746	5736733	Control	WB	South
2011.33C	748.0	472031	5736977	Control	NVEG	South
2011.33T	750.1	472094	5736970	Treatment	NVEG	South
2011.34T	749.1	472253	5737022	Treatment	NVEG	South

Appendix 9-D: Results of survivorship and vigour analysis of treatment sites in 2013

Site	Treatment	Year Planted	Frame Number	Live Plants	Dead Plants	Total Plants[10]	Survivorship	Vigour
2011.01T	PS	2010	1	0	0	58	0	Poor
			2	0	0	58	0	Poor
			3	0	0	58	0	Poor
2011.02T	PS	2010	1	0	0	58	0	Poor
			2	0	0	58	0	Poor
			3	0	0	58	0	Poor
2011.03T	PS	2010	1	7	0	58	12	Poor
			2	1	0	58	2	Poor
			3	6	0	58	10	Poor
2011.05T	PS	2010	1	0	0	58	0	Poor
			2	0	0	58	0	Poor
			3	0	0	58	0	Poor
2011.06T	PS	2009	1	0	0	58	0	Poor
			2	0	0	58	0	Poor
			3	0	0	58	0	Poor
2011.07T	PS	2009	1	20	0	58	34	Good
			2	13	0	58	22	Good
			3	16	0	58	28	Good
2011.13T	PS	2009	1	0	0	58	0	Poor
			2	0	0	58	0	Poor
			3	0	0	58	0	Poor
2011.14T	HPL/PS	2009	1	0	0	58	0	Poor
			2	0	0	58	0	Poor
			3	0	0	58	0	Poor
2011.15T	PS	2009	1	0	0	58	0	Poor
			2	0	0	58	0	Poor
			3	0	0	58	0	Poor
2011.16T	PS	2009	1	0	0	58	0	Poor
			2	0	0	58	0	Poor
			3	0	0	58	0	Poor
2011.17T	PS	2009	1	0	0	58	0	Poor
			2	0	0	58	0	Poor
			3	0	0	58	0	Poor
2011.18T	PS	2009	1	0	0	58	0	Poor
			2	0	0	58	0	Poor
			3	0	0	58	0	Poor
2011.20T	HPL/PS	2009	1	0	0	58	0	Poor
			2	0	0	58	0	Poor
			3	0	0	58	0	Poor
2011.21T	HPL	2008	1	0	0	n/a	0	Poor
			2	0	0	n/a	0	Poor
			3	0	0	n/a	0	Poor
2011.22T	HPL	2008	1	1	11	12	8	Poor
			2	0	5	n/a	0	Poor

[10] Estimated values only for PS treatment

Site	Treatment	Year Planted	Frame Number	Live Plants	Dead Plants	Total Plants[10]	Survivorship	Vigour
			3	0	11	n/a	0	Poor
2011.23T	PS	2010	1	21	0	58	36	moderate
			2	15	0	58	26	Poor
			3	26	0	58	45	moderate
2011.25T	PS	2010	1	0	0	58	0	Poor
			2	0	0	58	0	Poor
			3	0	0	58	0	Poor
2011.27T	PS	2010 AND 2011	1	0	0	58	0	Poor
			2	0	0	58	0	Poor
			3	0	0	58	0	Poor
2011.28T	PS	2010 AND 2011	1	0	0	58	0	Poor
			3	0	0	58	0	Poor
				10	0	58	17	moderate
2011.29T	PS	2010	1	5	0	58	9	Poor
			2	7	0	58	12	Poor
			3	11	0	58	19	Poor
2011.30T	PS	2010	1	0	0	58	0	Poor
			2	0	0	58	0	Poor
			3	0	0	58	0	Poor
2011.31T	PS	2011	1	0	0	58	0	Poor
			2	0	0	58	0	Poor
			3	0	0	58	0	Poor
2011.32T	PS	2011	1	17	0	58	29	moderate
			2	15	0	58	26	moderate
			3	24	0	58	41	moderate
2011.33T	PS	2011	1	40	0	58	69	moderate
			2	30	0	58	52	moderate
			3	52	0	58	90	moderate
2011.34T	PS	2011	1	48	0	58	83	moderate
			2	59	0	58	100	Good
			3	24	0	58	41	moderate

Appendix 9-E: Carbon (C) content (per cent dry weight) of vegetation biomass samples collected in 2013

Plot	% dry weight
2011-1 C	39.80
2011-2 C	43.20
2011-7 C	35.90
2011-8 C	35.00
2011-13 C	20.40
2011-15 C	22.10
2011-16 C	33.80
2011-25 C	39.40
2011-30 C	Insufficient quantity
2011-31 C	40.60
2011-32 C	42.80
2011-1 T	37.90
2011-2 T	Insufficient quantity
2011-3 T	32.70
2011-6 T	42.30
2011-10 T	37.60
2011-13 T	Insufficient quantity
2011-14 T	39.00
2011-15 T	37.50
2011-16 T	35.20
2011-24 T	37.40
2011-25 T	34.70
2011-27 T	41.60
2011-28 T	40.10
2011-29 T	41.50
2011-30 T	37.70
2011-32 T	35.50
2011-05 T	37.80
2011-05 C	36.50
2011-22 C	37.90
2011-21 T	Insufficient quantity
2011-21 C	Insufficient quantity
2011-04 C	36.80
2011-19 T	Insufficient quantity
2011-19 C	Insufficient quantity
2011-12 T	Insufficient quantity
2011-12 C	41.20
2011-11 C	36.00