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: 2011

LGL Limited
environmental research associates
Sidney, BC

March 2012

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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 3 – 2011 Annual Report

Prepared for

BC hydro

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Water Licence Requirements
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The content of this document was developed and prepared by LGL Limited environmental research associates for the specific purposes of the following project:

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 12, 2011

LGL Limited's proposal was submitted to BC Hydro on March 18, 2008 and the project was awarded to LGL Limited on April 8, 2008. Doug Adama of BC Hydro is administering this project.

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

EXECUTIVE SUMMARY

This year marked the third 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 2011, more than 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.

Since the initiation of the CLBMON-9 monitoring program, the primary objective has been to assess the vegetation characteristics of the revegetated areas to determine if the stated revegetation objectives of CLBWORKS-1 are being met. A secondary objective of this monitoring program has been to assess the natural vegetation communities in the reservoir, although this objective overlaps greatly with the objectives of CLBMON-10 (Kinbasket Reservoir Inventory of Vegetation Resources). In 2011, however, the focal objective was on revegetation effectiveness monitoring and not on the characterization of existing vegetation communities.

In 2011 an attempt was made to sample all combinations of geographic region, elevation, vegetation community type and revegetation prescription that occurred in the north and south ends of the reservoir. Twelve of the 19 vegetation communities described in Hawkes et al. (2007) were sampled in 2011. This included both existing vegetation and treated areas, although the assessment of the treated areas was the primary focus of sampling in 2011. In addition to assessing characteristics such as per cent cover, plant species diversity and species richness in treated plots and adjacent control plots, larger plots were established in 2011 to assess the actual survivorship and vigour of treated areas. In order to assess the quality of the soils, as well as how well the soil nutrients were being taken up into the establishing vegetation, soil and vegetation samples were sent to the laboratories of Guelph University to be analyzed for a variety of nutrients.

No statistically significant differences were noted in the vegetation between the treatment and control plots in any of the analyses that were performed. Neither per cent cover of vegetation, plant species diversity nor plant species richness differed significantly, although some significant differences were noted in these characteristics in different regions of the reservoir or between different elevation bands (as expected). However, some minor trends were noted between treatment and control plots, such as slightly higher per cent cover, plant species diversity and species richness at sites that had received both hand-planted stakes and a plug seedling treatment. Analysis of survivorship and vigour indicated that treated plots were experiencing large-scale mortality over the first two years following planting, with fewer than 40 per cent of sedge plugs alive after two growing seasons. Similarly, the assessed vigour of treated plots shifted dramatically from overwhelmingly good during the first year after planting to overwhelmingly poor or moderate two years later. Soil and vegetation nutrient

analysis did not demonstrate any substantial differences between the treatment and control plots, with the exception of the much higher carbon:nitrogen ratio in treated plots (vs. control plots) at high elevations in northern parts of the reservoir.

The trends in survivorship and vigour, in combination with the determination that the revegetation program is failing to significantly increase the vegetation cover or plant species diversity at any of the sites, indicates that the CLBWORKS-1 program is failing to meet its stated objectives. Because the program is not meeting these objectives, a number of recommendations that may improve the survivorship of the revegetated polygons are put forward in this document. These recommendations range from relatively minor changes in the planting methodology to larger scale alterations such as changes to the reservoir operating regime or the initiation of physical works projects. It is apparent from the 2011 assessment, though, that without some adaptive management, the program will likely continue to struggle and any successes in establishing vegetation in the drawdown zone will be relatively minor.

All management questions described for the CLBMON-9 monitoring program have been addressed or, in some cases, will be addressed once a larger data set is available for analysis. The following table summarizes the management questions and hypotheses associated with CLBMON-9 and includes a brief summary of the data required, current status and (key) preliminary results associated with each management question. An indication of whether or not we think the management question will be addressed by this monitoring program and the associated field and analytical methods is provided.

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 (quadrats), lab data	Ongoing; many revegetation polygons were characterized in 2011	No significant differences in quality and quantity of vegetation between treated and untreated plots, at least at the landscape scale
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}			Yes	Field data (survivorship plots)	Ongoing; many revegetation polygons were characterized in 2011	Steep decline in survivorship of sedge plugs each year following 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}	Yes	Time series data (minimum of 5 years)	Approaching ability to determine these relationships, but require at least two more years of data	Specific data on the relationships between revegetation effectiveness and reservoir operations will be forthcoming
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}	Yes	Field data (quadrats, survivorship plots), lab data	Ongoing; many revegetation polygons were characterized in 2011	Widely variable results among individual plots and treatments, with no significant differences among treatments
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}	Yes	Review of CLBMON-10 annual reports, time series data	See Hawkes et al. (2010) for most recent assessment.	See Hawkes et al. (2010) for most recent assessment, including mapping of vegetation communities
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}	Yes	Review of existing literature, past reports, and current status of the revegetation program	A review of the effectiveness of the current revegetation program, including opportunities for additional improvements, is presented in this report	Several opportunities exist for improvements to the revegetation project in 2011, as discussed in Sections 6.0 and 8.0 of this report

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.

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

ACKNOWLEDGEMENTS

Doug Adama of BC Hydro administered this project and provided technical assistance and data. Doug Adama and Guy Martel completed a QA and Safety audit of CLBMON-10 in July 2011. Jamie Fenneman (LGL), Jeremy Gatten (LGL) and Mike Miller (Michael Miller Consulting) collected field data. Tracey D. Hooper provided valuable technical editing of the report prior to submission. Pascale Gibeau (EcoFish) assisted with data analyses.

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1.0 INTRODUCTION

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), which makes it one of the largest artificial reservoirs in the world. 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. Much of the drawdown zone has only sparse vegetation cover as a result of the large variations in water levels, which impacts ecosystem functioning, wildlife values, and aesthetics within the drawdown zone. These cumulative impacts of reservoir management 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 significant 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 that is compatible with the current operating regime to maximize vegetation growth in the drawdown zone (BC Hydro 2005). The program was proposed as a multi-year project requiring intervention over five years to facilitate the development of long-term vegetation cover. 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 vegetation development due to coarse substrates and steep slopes, 68 sites were found to support existing vegetation, the two largest sites being Bush Arm (1,169 ha) and Canoe Reach (698 ha). An additional 1802 ha of shoreline were identified as having either high or moderate potential for enhancement.

As a result of these findings, a revegetation program was initiated in 2007 to enhance the existing vegetation communities and to vegetate currently unvegetated areas within the upper portion (~741 m to 754 m ASL) of the drawdown zone. Among the studies implemented under the WUP are two vegetation monitoring programs. Kinbasket Reservoir Inventory of Vegetation Resources (CLBMON-10) was initiated in 2007 and is designed to monitor inter-community changes in existing vegetation communities at the landscape scale within the drawdown zone of Kinbasket Reservoir. The second program, Monitoring of Revegetation Efforts and Vegetation Composition Analysis (CLBMON-9), began in 2008 and aims to (a) monitor the small (site) scale

[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.

vegetation changes within the upper (~741 m–754 m ASL) drawdown zone over 10 years, and (b) monitor revegetation efforts conducted under Kinbasket Reservoir Revegetation Program Physical Works (CLBWORKS-1).

The environments occurring within the drawdown zone of any reservoir 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. For example, the typical hydroperiod of a body of freshwater 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 thus 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, the water levels are typically maintained at low levels throughout the winter and spring to allow for the capture of waters of the spring freshet. Thus, water levels actually tend to rise (often dramatically) throughout the spring and summer, inundating vegetation as it attempts to grow (Abrahams 2006). Other factors such as 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 establishing vegetation in the drawdown zone. These challenges apply to both revegetated areas as well as naturally vegetated sites.

This report describes the Year 3 (2011) results of CLBMON-9, including 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. A primary focus of this report is the summary of the effectiveness of revegetation efforts up to 2011, including both successes and failures. This includes (but is not limited to) factors such as pre-planting planning, sourcing of stock, planting methodologies and adaptive management. The report also provides recommendations based on these results which will improve the program through 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 m–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.

This study focuses partially on monitoring existing vegetation at the site (local) scale, although this was not a primary component of the 2011 monitoring season. Observations of intra-community changes in existing vegetation over a 10-year time horizon 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.

This study also assesses the effects of revegetation efforts at the site-scale through plot-based monitoring; this was the primary focus of the monitoring program during 2011. 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 m 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 m 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)?

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

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?
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 m ASL 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

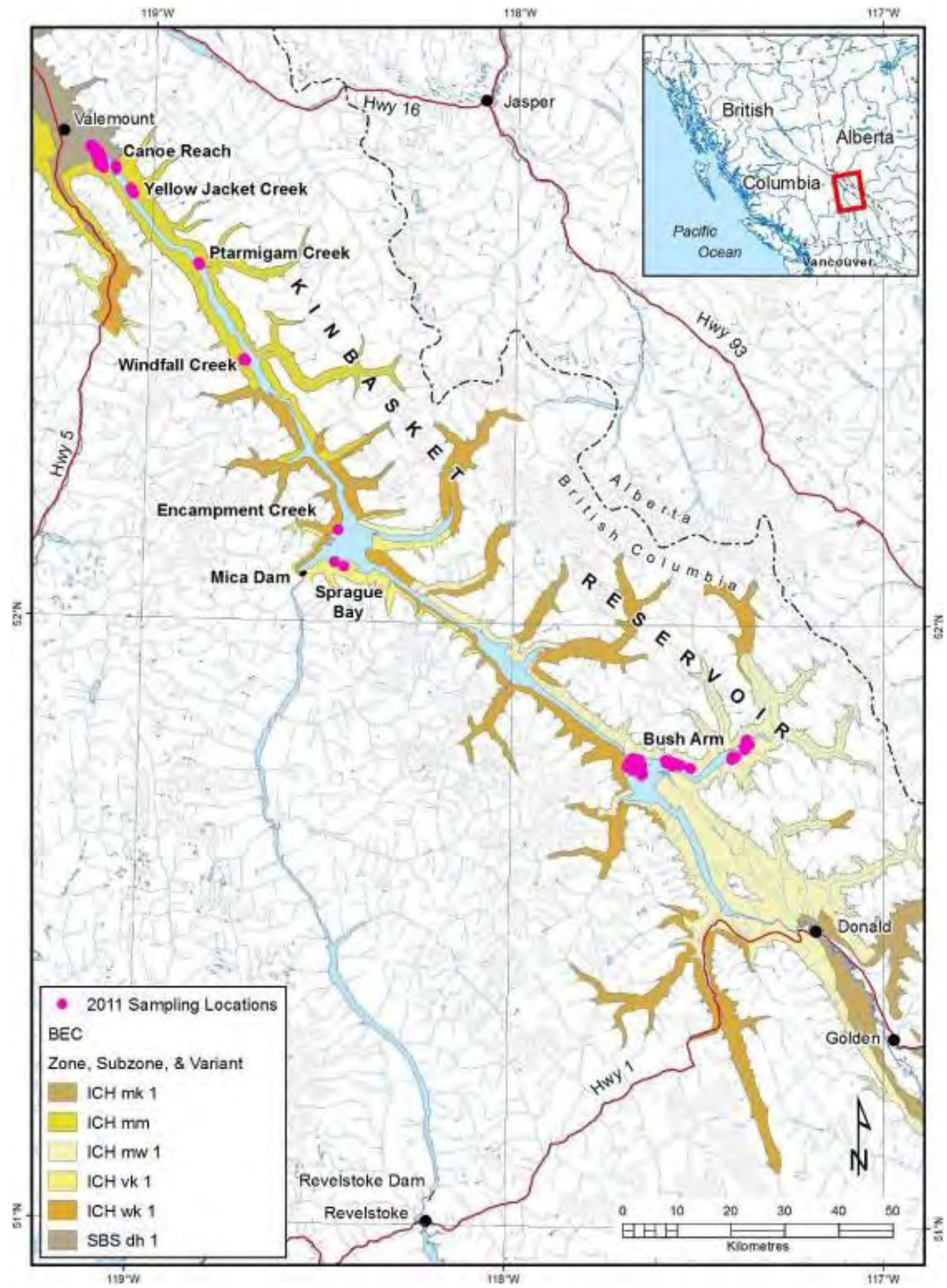


Figure 3-1: Location of Kinbasket Reservoir and vegetation sampling locations (pink). Landscape unit names (e.g., Bush Arm, Encampment Creek) were assigned to each area sampled in 2011. Refer to Table 3-1 for descriptions of biogeoclimatic (BEC) zones

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 m 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*a*, 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 plants) to more disturbed types dominated by non-wetland plants. Large areas

[6] From BC Hydro 2007 after BC Hydro 1983

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 peninsulae 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 two broad geographic areas within Kinbasket Reservoir: the south (Bush Arm [Figure 3-2, Figure 3-7]) and the north (Canoe Reach, Mica Creek [Figure 3-3, Figure 3-4, Figure 3-5, Figure 3-6]). Sampling of both existing vegetation and revegetation polygons was conducted in both geographic areas in 2011.

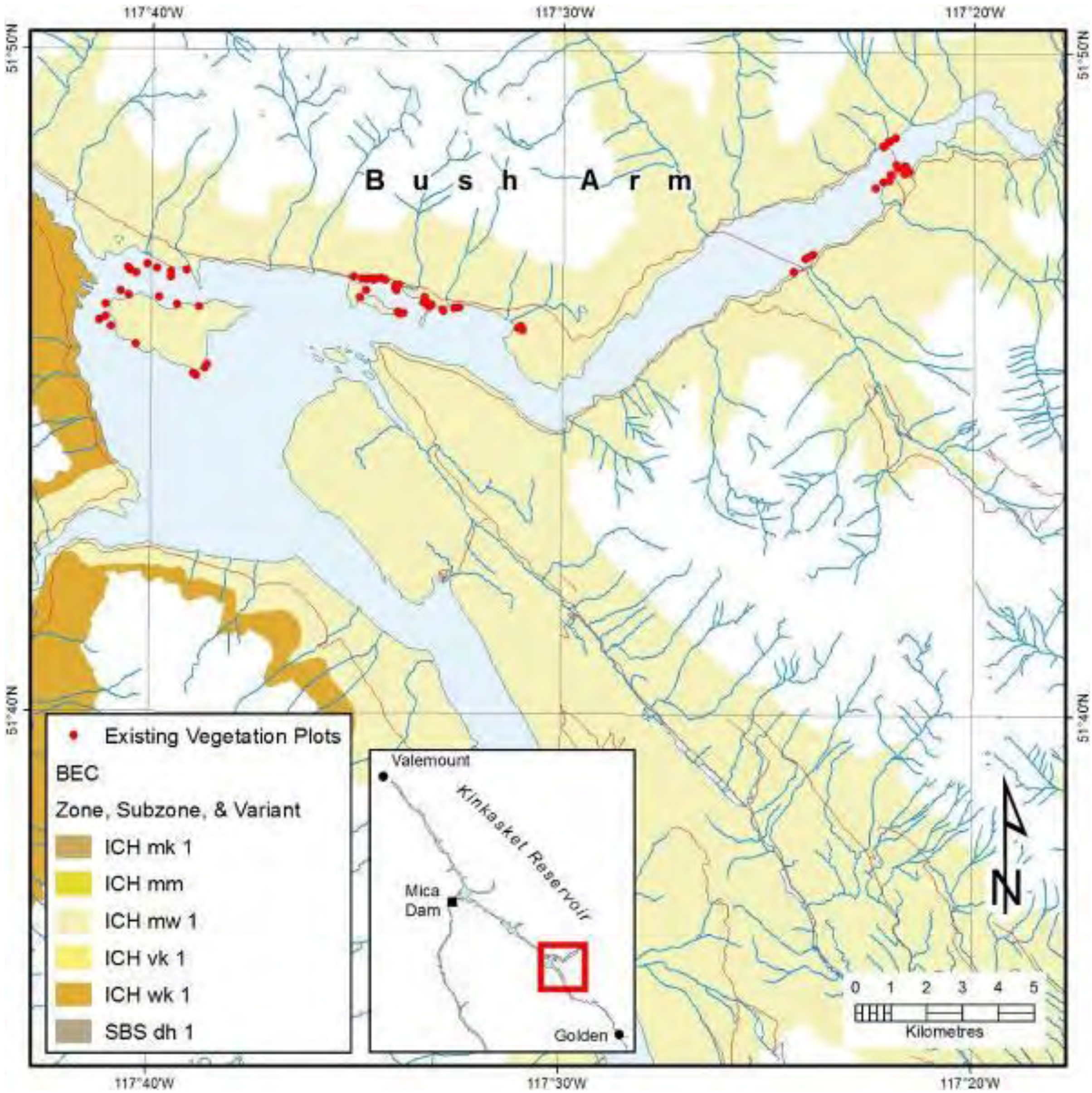


Figure 3-2: **Locations of 2011 samples of existing vegetation in the south end of Kinbasket Reservoir. Refer to Table 3-1 for descriptions of biogeoclimatic (BEC) zones**

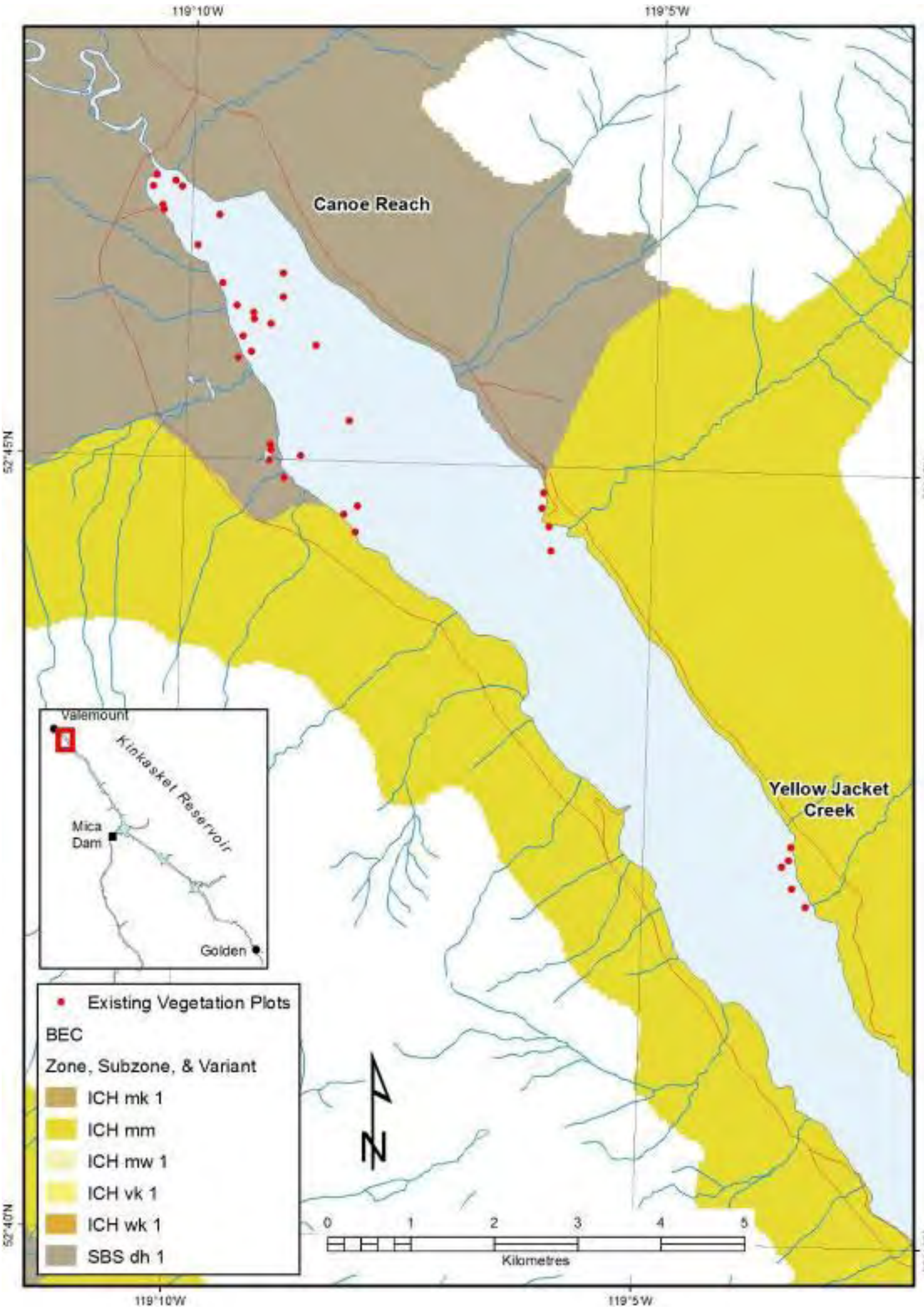


Figure 3-3: **Locations of 2011 samples of existing vegetation in the north end of Kinbasket Reservoir. Refer to Table 3-1 for descriptions of biogeoclimatic (BEC) zones**

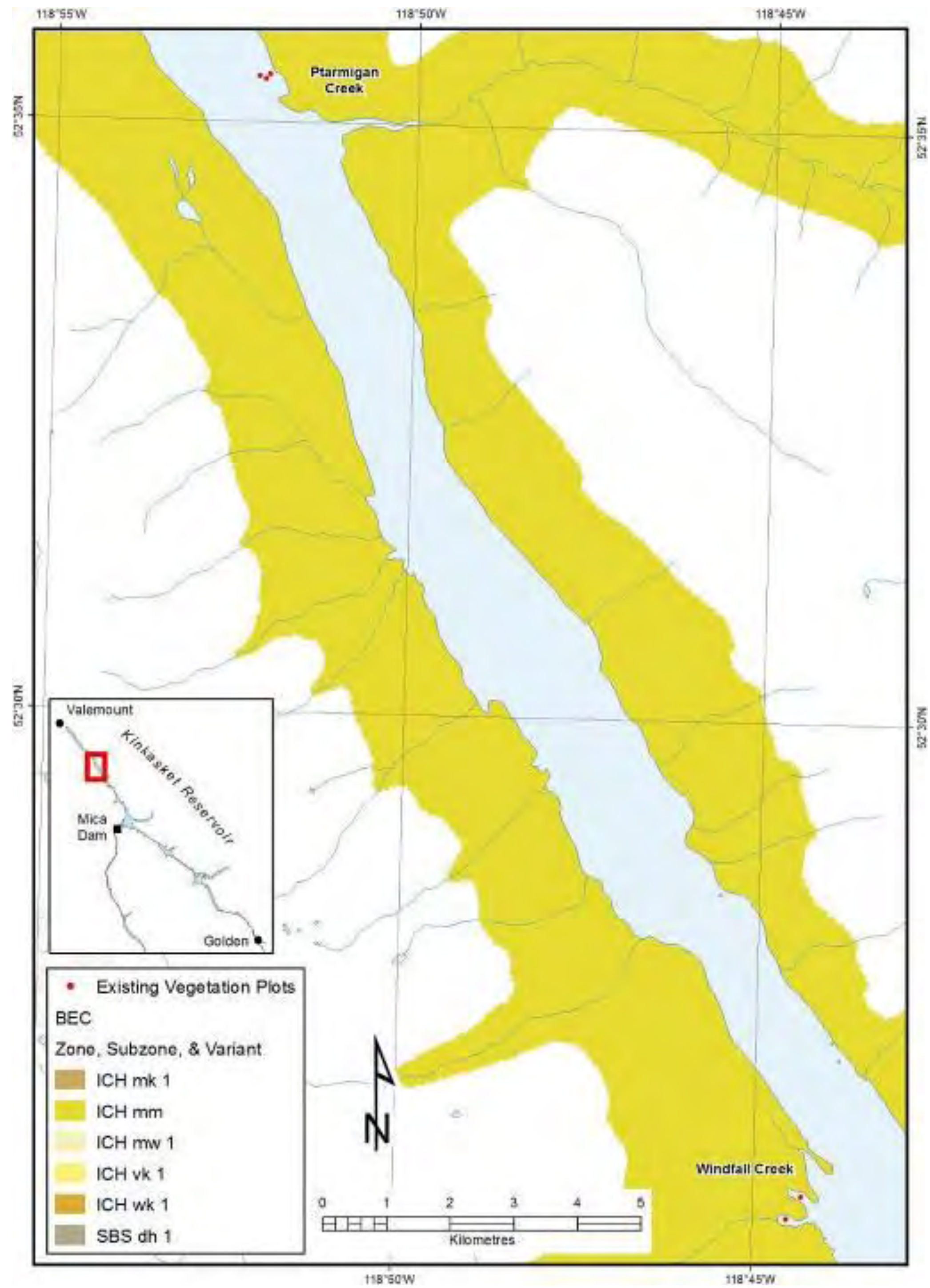


Figure 3-4: Locations of 2011 samples of existing vegetation in the Ptarmigan Creek and Windfall Creek areas in the north portion of Kinbasket Reservoir. Refer to Table 3-1 for descriptions of biogeoclimatic (BEC) zones

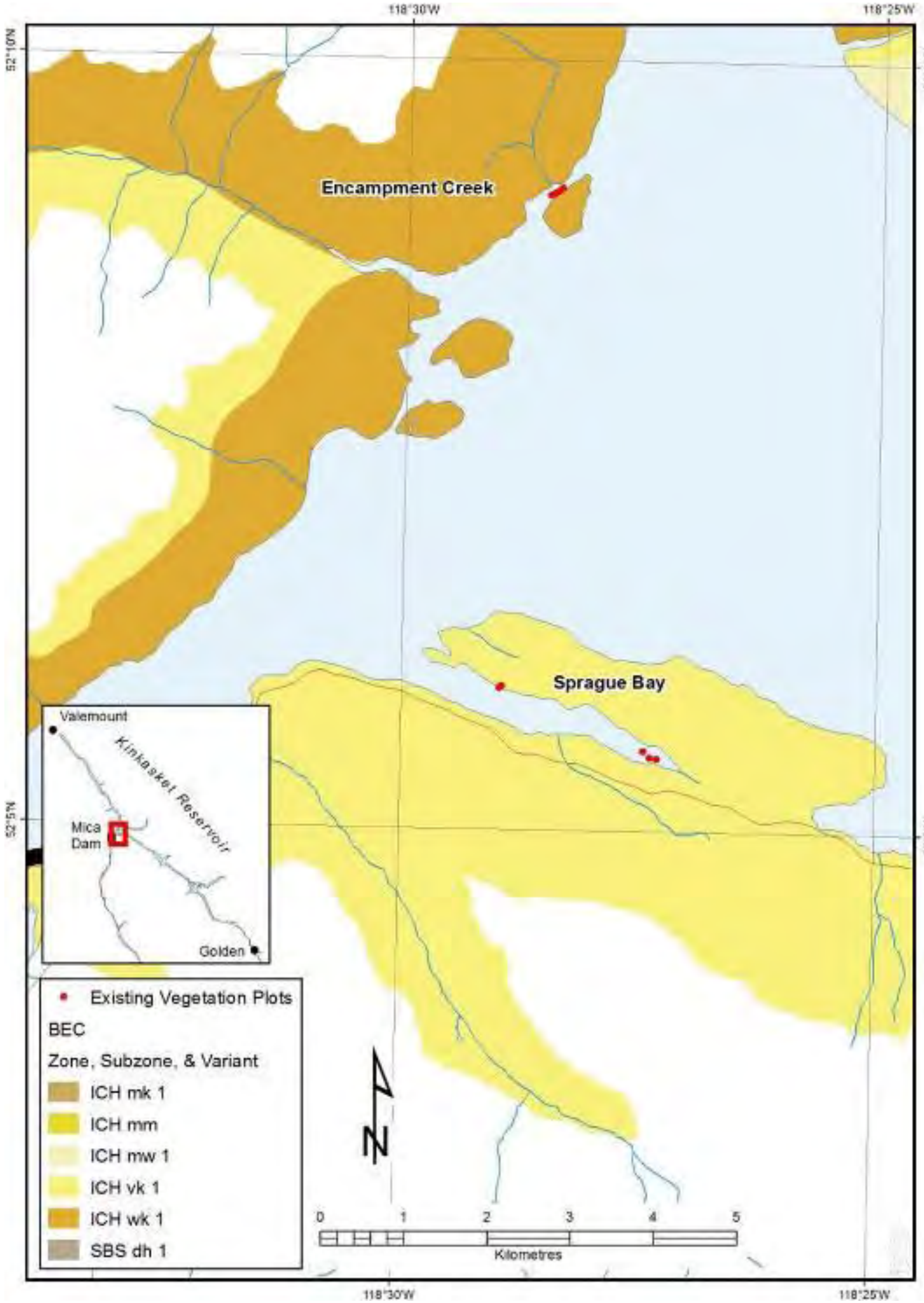


Figure 3-5: **Locations of 2011 samples of existing vegetation in the Mica Creek area (central region) of Kinbasket Reservoir. Refer to Table 3-1 for descriptions of biogeoclimatic (BEC) zones**

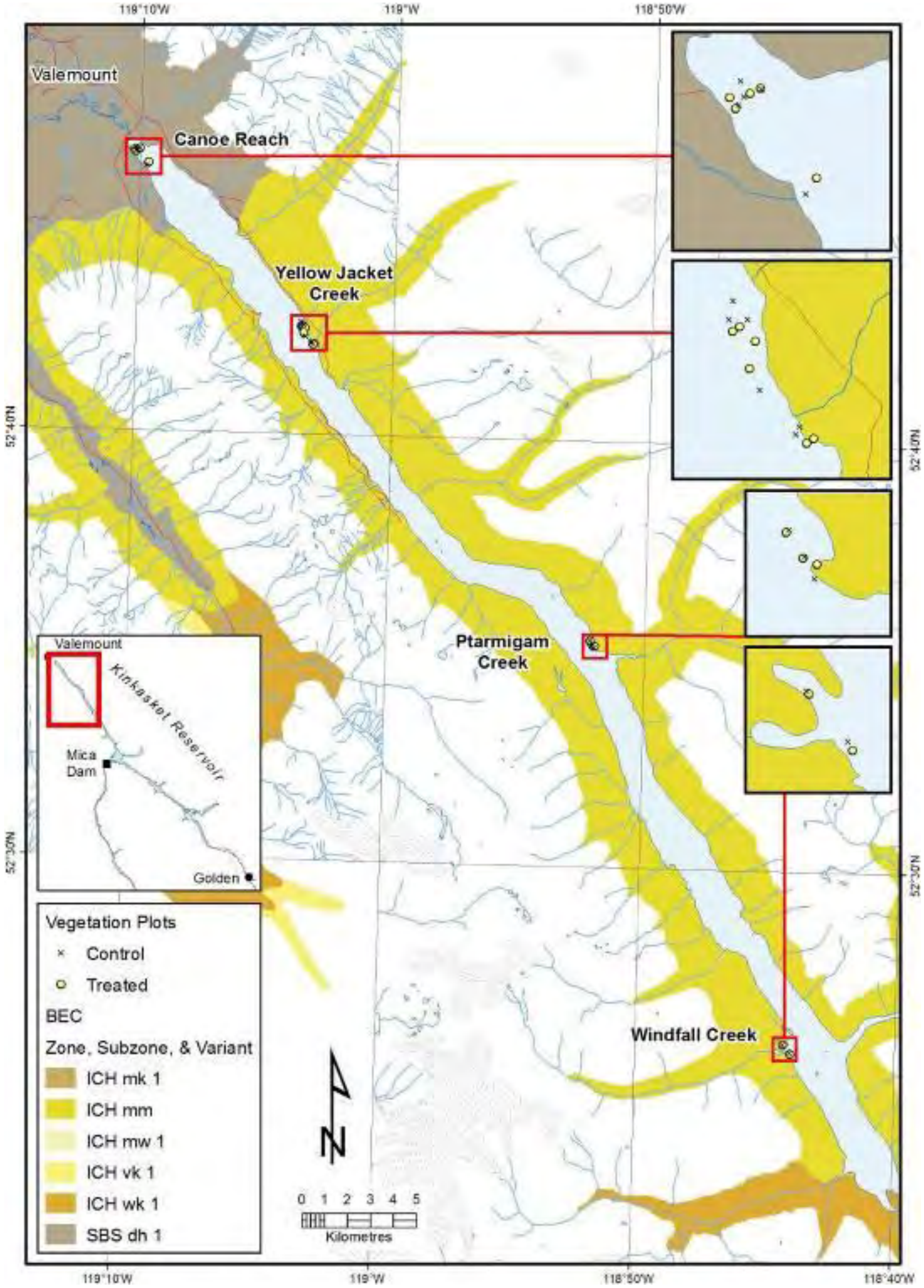


Figure 3-6: **Locations of 2011 samples of revegetated areas (treated plot: yellow circle; control plot: black "x") in the north end of Kinbasket Reservoir. Refer to Table 3-1 for descriptions of biogeoclimatic (BEC) zones**

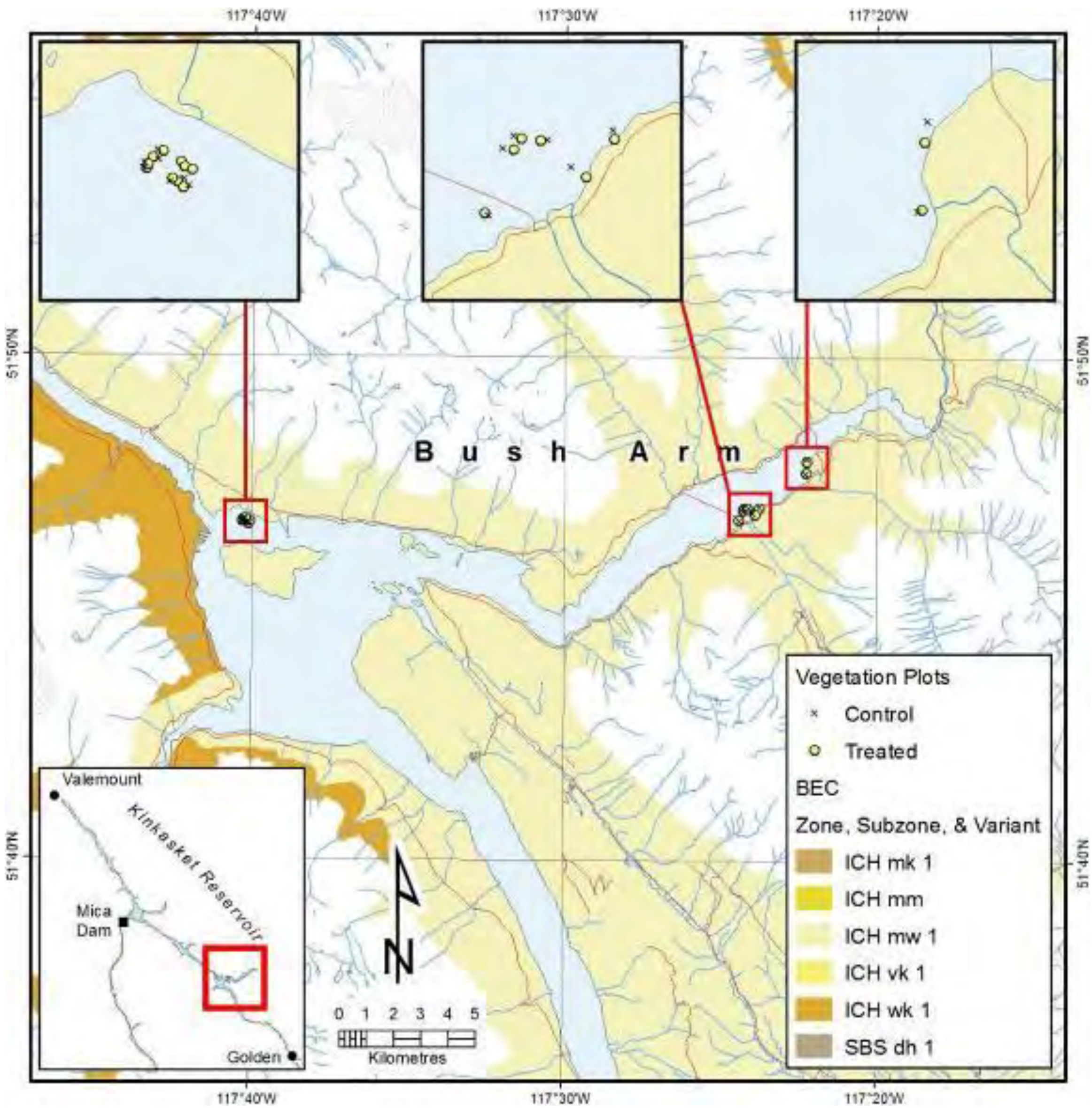


Figure 3-7: **Locations of 2011 samples of revegetated areas (treated plot: yellow circle; control plot: black "x") in the south end of Kinbasket Reservoir. Refer to Table 3-1 for descriptions of biogeoclimatic (BEC) zones**

4.0 METHODS

4.1. Study Design

A similar study design was applied to both the existing vegetated and revegetated areas and was based on the methods implemented by Yazvenko et al. (2009), which are described below. Some minor changes were made in 2011 to ensure that all strata were sampled.

Sampling was stratified based on four variables:

1. **Geographic area.** Two areas were sampled: (1) the north (Canoe Reach) and (2) the south, including Bush Arm. The responses of plant communities to operational regime and other factors may differ between geographic areas but are assumed to be similar within each area.
2. **Vegetation community.** We followed the vegetation classification system developed by Hawkes et al. (2007; Table 4-1). The goal was not to sample all 18 types; rather, the intent was to focus on sampling more common types in order to obtain adequate sample size and increase the power of the analysis (Zuur et al. 2007).

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

Vegetation Community Code	Vegetation Community Type	Sampled in 2011
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	No
LH	Lodgepole Pine - Annual Hawksbeard	No
RC	Reed Canarygrass	No
CR	Common Reed	No

Of the remaining seven community types, two (DR: Driftwood and WD: Woody debris) had little or no vegetation, FO: Forest is located above the drawdown zone, and the rest are rare.

3. **Elevation.** We blocked elevations into three groups:

- 741-745 (Low elevation zone, 5 m ASL wide)
- 746-750 (Mid elevation zone, 5 m ASL wide)
- 751-754 (High elevation zone, 4 m ASL wide)

The uppermost stratum contains a 4 m elevation range, vs. 5 m for each of the lower strata. In the inevitable situation of inequality of the strata (14m / 3), we feel it is better to compress the upper stratum.

4. **Revegetation prescription:** Eight different revegetation prescriptions have been applied in the drawdown zone of Kinbasket Reservoir since 2008 (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) We restricted our assessment of revegetation effectiveness to hand-planted stakes (HPL), hand-planted stakes and plug seedling (HPL/PS), hand seeding (HS) and plug seedling (PS). These prescriptions were selected because sample size and replication was highest within these prescriptions.

Efforts were made to sample all combinations of all strata in north and south of the reservoir; however, not all combinations of strata exist in both geographic regions. A sampling plan was developed to ensure that all combinations of strata that did exist in each geographic region were sampled in 2011.

4.1.1. Kinbasket Reservoir Vegetation Communities

The vegetation community maps developed for the 2010 sampling year for CLBMON-10 (Hawkes et al. 2010) were used as the basis for sampling in 2011. These maps updated the maps produced in 2007 and are considered to be a more accurate representation of the distribution of vegetation communities in the drawdown zone of Kinbasket Reservoir than are either the 2007 or 2008 maps.

4.1.2. Existing Vegetation

Existing vegetation was assessed in 2011 using the methods described in Yazvenko et al. (2009) (see Appendix A). The only difference in 2011 was that sampling was conducted in both the north and south ends of the reservoir, and additional plots were added to sample vegetation communities that (1) were not sampled in previous years, (2) were not sampled in certain combinations of each strata, or (3) required more sampling to better characterize the variation within the community type more thoroughly.

As in previous years we followed the vegetation classification system developed by Hawkes et al. (2007). The goal was not to sample all 19 vegetation community types; rather, the intent was to focus on sampling more common types in order to obtain an adequate sample size and increase the power of the analysis (Zuur et al. 2007). Some types are devoid of vegetation or are rare and/or hard to access, which made adequate sampling too time consuming given time and budget constraints. Therefore, we selected 12 of the more common and/or widespread community types for sampling (Table 4-1).

4.1.3. Revegetated Areas

We attempted to sample all combinations of geographic region, elevation, vegetation community type and revegetation prescription that occurred in the north and south ends of the reservoir. Not all combinations of all strata were available in the north and south, which is due mainly to the differential distribution of vegetation communities in the drawdown zone (see Hawkes et al. 2010).

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 plots were established in both the north and south. Some of the plots sampled in 2011 were plots that were established in 2008 or 2009; however, most plots sampled in 2011 were sampled for the first time. This is because sampling in 2008 and 2009 did not consider revegetation treatment as a stratum, so the sampling was not representative of the manipulation of the drawdown zone.

The 2011 plot centres (i.e., the location from which the three quadrats would be thrown) 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 and the Kinbasket digital elevation model. For every combination of elevation, vegetation community and revegetation prescription that occurred in the north and south ends of Kinbasket Reservoir, we selected a plot centre for both a treatment (revegetation treatment) and control (not treated as part of the revegetation program) to derive a series of paired (treatment and control) samples.

The location of the plot samples 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 vegetation community polygons and the revegetation treatment polygons will remain intact over time, and the plots established in 2011 can be sampled again in the future to derive a time series dataset.

4.1.3.1. Survivorship

The survivorship of plants used in the revegetation program was assessed in 2011 through the use of two or three (depending on the size of the revegetation polygon) 5 x 5 m plots that were established in each combination of revegetation type, elevation strata, vegetation community code and geographic area. Only revegetated areas were assessed for survivorship. The 5 x 5 m plots were positioned to represent the overall condition of the plants in each plot. Within these plots 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. In addition, the overall vigour of the plants in the plot was assessed, with each plot being assigned a vigour value of good, moderate or poor, based on professional judgement.

4.1.3.2. Field Sampling

Once on the ground, a researcher stood at the predetermined plot centre and threw the 0.71 m x 0.71 m (0.5 m^2) quadrat three times around the point within the plot to be sampled. This is a standard technique of describing non-forest vegetation (Mueller-Dombois and Ellenberg 1974, Bonham 1989). The location of the centre of the plot was marked with a rebar stake driven into the ground to the height of ~10 cm to 15 cm. The top of each piece of rebar was capped with a bright orange construction safety cap to (a) facilitate plot relocation in subsequent sampling years and (b) lessen the hazard of hitting it. The location of each 0.5 m^2 quadrat was georeferenced using a precision (submetre) SX-Blue GPS unit. Every quadrat was oriented north–south.

Each treatment plot was paired with a control plot (three quadrats thrown per treatment and control plot). Controls were established in 10 x 20 m control plots 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). Control plots 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 plots 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 plots sampled in the various strata of the design to absorb up to a 10 per cent loss of plots without affecting incommensurably the statistical power of the tests. Barring a physical disappearance of a plot, 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 plots will continue.

4.1.3.3. Vegetation Data

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. (1998*a*, 1998*b*, 1999*a*, 1999*b*, 2000, 2001*a*, 2001*b*, 2002) with current amendments. Vegetation 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

Estimates of species cover as a proxy for species abundance were conducted in the field visually and separately for each species. Species cover was estimated in each quadrat, and a mean per cent cover per quadrat was computed in office. Percentage cover was visually estimated and rounded using percentage binning developed by Domin and Krajina (Krajina 1969):

- <0.01% - traces

- <0.1% - rare and solitary species
- <1% - scattered small plants
- 1-10% - rounded to nearest 1 per cent
- 11-30% - rounded to nearest 5%
- 31-100% - rounded to nearest 10%.

Vegetation vigour was assessed using a qualitative scale of good, moderate, and poor. Good was defined as the majority of plant (> 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 5-0 and 75 per cent) surviving and mostly healthy (some yellowing or wilting) and 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 with plant survivorship.

4.1.3.4. Environmental Data

The natural or anthropogenic factors that influence vegetation establishment at a given site were recorded (Table 4-2).

Table 4-2: Summary of the environmental variables judged *a priori* as important with regard to their effects on vegetation

Variable			Type	Units (Categories)
Computed in the office	Water operating regime[a]	Timing of inundation	Quantitative	Date (start) and date (end)
		Frequency of inundation	Quantitative	Time/Year
		Duration of inundation	Quantitative	Days
		Depth of inundation	Quantitative	Metres
	Topographic effect	Slope	Quantitative	Degrees
		Aspect	Quantitative	Degrees
	Geographic area	Geographic zone	Categorical	Zone name
	Environmental variables[a]	Temperature (daily and monthly averages)	Quantitative	Degrees Celsius
		Precipitation (daily and monthly averages)	Quantitative	mm
	Temporal variables[a]	Year of sampling	Quantitative	Year
		Date of sampling	Quantitative	Date
		Date of sampling adjusted to phenological progression[b]	Quantitative	Date
d fro m fiel	Spatial variables	Geographic coordinates	Quantitative	Deg/min/sec

Variable			Type	Units (Categories)
	Site substrate data	Organic matter – live and dead	Quantitative	kg/m^2
		Decayed wood	Quantitative	per cent area
		Bedrock	Quantitative	per cent area
		Rock	Quantitative	per cent area
		Mineral soil	Quantitative	per cent area
		Water (standing or flowing)	Quantitative	per cent area
		Erosion/deposition[a]	Rank (estimated) or quantitative (measured)	Code or vertical cm

[a] Parameters not estimated/analyzed in 2011
[b] Each year, the sampling period was selected to cover vegetation in a roughly similar phenological phase, within logistical and other constraints.

4.1.3.5. 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 plot (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 plots but not for existing vegetation plots. 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 to the University of Guelph for analysis following the completion of each field session.

4.1.3.6. Vegetation Biomass and Nutrient Analysis

Vegetation samples were collected at each treatment and control plot for analysis of nutrient content. Within one of the three quadrats at each of these plots, a 0.5 x 0.5 m subplot was installed from which a vegetation sample was collected. Within this subplot all aboveground vegetation matter was collected.. The clipped vegetation was dried in the field using a botanical press. Biomass was analyzed for dry weight (samples dried in the field in botanical press, then dried to a constant weight, i.e., samples were repeatedly measured until their weight reached an asymptote) at 70 °C for approximately 72 h, then weighed to the nearest 0.01g using standard methods, (USDA-NRCS 1997). Dry weight, ash-free dry weight (i.e., organic dry weight), N, P, K and C were measured in each sample. Biomass and nutrient analyses were completed by the University of Guelph.

4.2. Statistical Analyses

The per cent cover of all vegetation species recorded on each plot sampled in each treatment, control, and existing vegetation was averaged to derive an estimate of total cover overall and per species for each transect. Trends among vegetation communities and landscape units were based on two or three years of data (i.e., 2008, 2009 and 2011).

Species richness, diversity and evenness 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 plots of each combination of strata. There are many ways to standardize richness (e.g., using the log of the number of individuals [Odum et al. 1960] or taking the square root of the number of individuals [Menkinick 1964]), and dividing by sampling effort might not be the most robust method (Gotelli and Colwell 2001), but other methods, such as rarefaction, are not appropriate for vegetation studies (Forbes et al. 2001). Forbes et al. (2001) go on to state that the use of a constant quadrat size (as we have done) appears to remain a robust and appropriate method for assessing and comparing species richness. Therefore, the use of a standardized metric of species richness, calculated from plots of equal size and used in conjunction with diversity indices that divide richness by proportion of individuals is appropriate for this study.

Diversity was computed as Shannon's entropy and corresponded to a measure of species composition, combining both the number of species and their relative abundances (Legendre and Legendre 1998). For each transect, diversity was computed as:

$$H = -\Sigma\ (pi \log pi)$$

where pi is the relative proportion of species i.

A value of 0 means that the sampling unit contains only one species; H then increases along with the number of species recorded in the sampling unit. A high value of H means that many species were recorded. The diversity value calculated by Shannon's entropy index (H) does not indicate how the species of vegetation are distributed within the transects established in each vegetation community. To determine the distribution of species by transect, vegetation community and landscape unit, Pielou's evenness was computed (Pielou 1966):

$$J = H/Hmax = (-\Sigma\ (pi \log pi))/\log q$$

where q is species richness.

The more J tends towards 1, the more evenly the different species are distributed; conversely, a value close to zero means that one or more species are dominating the community (i.e., the distribution is uneven).

Using both diversity and evenness indices together provides insight into the composition of the existing communities and revegetated areas, as well as the distribution of species within the plots. For example, the diversity of a plot could be high, but its evenness index low, suggesting that although the plot has a high diversity of species of vegetation, one or two are dominating and the other species occur infrequently (interspecific competition is high). However, the same high diversity index combined with a high evenness index would mean that the plot has a diversity of vegetation species that are equally frequent (interspecific competition is low).

Richness, diversity and evenness of vegetation according to geographic location, revegetation prescription, vegetation communities and elevation were summarized through box plots (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 species richness, diversity and evenness 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 2.9.2) and the F-distribution was tested with 99,999 permutations.

4.3. Laboratory Analyses

4.3.1. Soil Samples

Laboratory analyses of the soil samples collected from treated and control plots 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)
- grain size distribution

4.3.2. Biomass Samples

Laboratory analyses of the biomass samples collected from treated and control plots 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)

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

- 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 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.

5.0 RESULTS

The emphasis of CLBMON-9 in 2011 was on revegetation effectiveness monitoring and not on the characterization of existing vegetation communities. However, data were collected from existing vegetation communities in every combination of elevation, vegetation community and geographic location considered for CLBMON-9 (i.e., the north and south ends of Kinbasket Reservoir). Other areas sampled under CLMBON-10 (e.g., Beavermouth, High Alan Bay) were not sampled in 2011. The data are summarized below. Because some of the plots resampled in 2011 were previously sampled in 2008 or 2009, it was possible to assess differences in species richness, diversity and abundance over time for those plots.

5.1. Field Sampling

Field sampling was conducted over two field sessions: June 14–28, 2011 and July 14–24, 2011. The dates for the 2011 field sessions were similar to those in 2008 and 2009 (Yazvenko 2009, Yazvenko et al. 2010). Reservoir elevations ranged from 736.38 m to 742.62 m ASL during the first field session and from 748.24 m to 751.10 m ASL during the second field session (Figure 5-1). Field sampling was conducted during periods when all elevation strata were available for sampling.

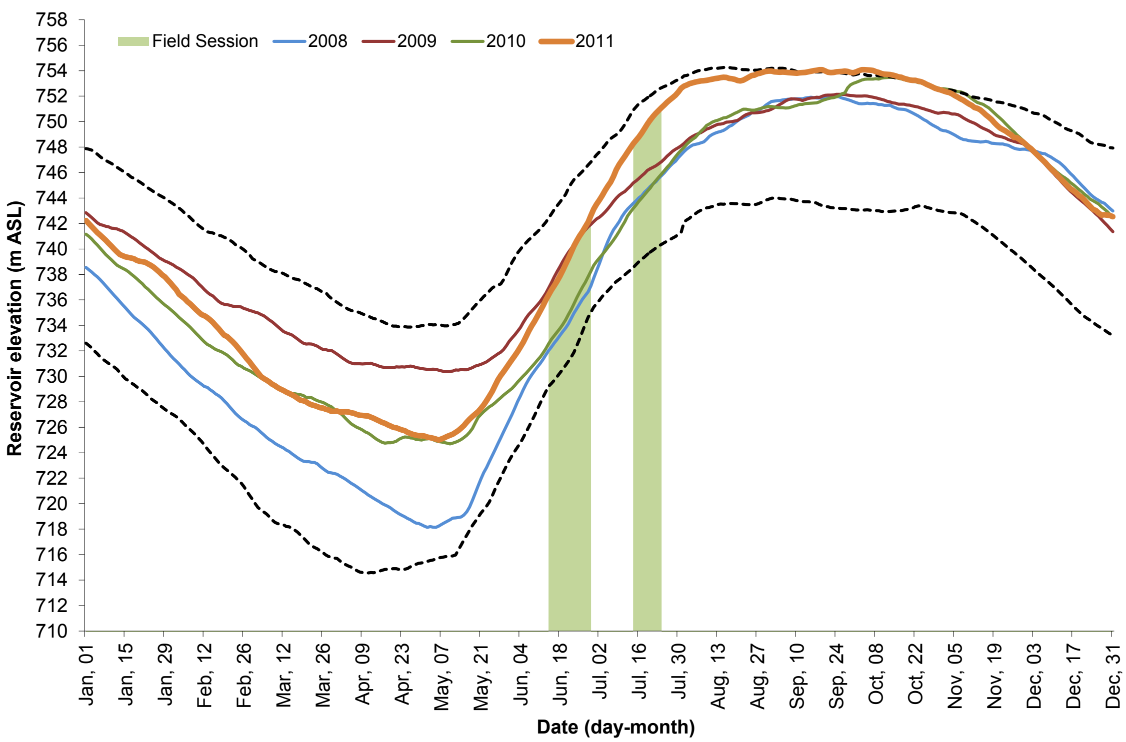


Figure 5-1: Kinbasket Reservoir elevations from January 1 through December 31, 2008, 2009 and 2010, and 2011. The 90th and 10th percentile values (dashed black lines) are also shown for the period from 1976 to present. The green shaded bars indicate the timing of the 2011 field sessions

5.2. Existing Vegetation

5.2.1. Sampling Effort

Existing vegetation communities were sampled through the north, central and southern reaches of Kinbasket Reservoir (Table 5-1). Most sampling was conducted in the north and the south to align with work completed in 2008 and 2009. Some sampling was also conducted in the vicinity of Mica Dam (i.e., the central region). The number of plots and vegetation communities sampled in each geographic strata varied relative to the distribution of, and access to, the various vegetation communities delineated for those regions. A total of 13 vegetation communities (12 vegetated, one non-vegetated) located at three elevation bands was sampled. Eight community types were sampled in the north, four in the central, and 11 in the south regions. A larger number of sample plots were scheduled for sampling in both field sessions, but many plots had to be removed from sampling due to access issues (such as road washouts) or, more often, inundation by the rapidly rising reservoir.

Table 5-1: Number of plots and vegetation communities (VC) sampled in existing vegetation per elevation and geographic strata in the drawdown zone of Kinbasket Reservoir in 2011. Data for 104 of 106 plots are shown

	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	--	--
BS	--	--	--	--	--	--	2	--	--
CH	1	--	1	5	--	4	1		2
CO	--	--	--	--	--	--	4	1	4
CT	--	--	--	--	--	--	--	--	2
KS	2	--	4	--	4	5	2	--	--
LL	5	--	8	1	--	2	1	--	--
MA	--	--	2	--	--	4	--	--	--
SH	--	--	--	--	--	1	--	--	5
TP	2	1	5	1	--	1	--	--	--
WB	--	1	--		2	3	2	--	--
WD	1	--	--	1	--	--	--	--	--
WS	--	--	--	--	--	--	3	--	4
No. plots	**11**	**2**	**20**	**8**	**6**	**22**	**17**	**1**	**17**
No. communities	**5**	**2**	**5**	**4**	**2**	**8**	**8**	**1**	**5**

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

Of the total plots sampled for existing vegetation in 2011 (104), 36 plots (108 quadrats) were located in the north (Canoe Reach), nine were located in the central reach (27 quadrats [Mica Creek]) and 59 plots (177 quadrats) were in the south (Figure 3-2, Figure 3-3, Figure 3-4, Figure 3-5, Appendix C).

5.2.2. Analysis of Existing Vegetation

Analyses were performed on existing vegetation data to determine background trends in vegetation characteristics during the first four years (2008–2011) of the monitoring program. Although multiple analyses were performed, the results of the Principal Components Analysis did not provide strong species associations, and therefore are not discussed further here. Comparisons of a variety of vegetation characteristics (per cent cover, species richness, species diversity and evenness) were made between 2008 and 2011 vegetation data for different regions of the reservoir (Figure 5-2), different vegetation communities (Figure 5-3) and different elevation bands (Figure 5-4). Most results showed little or no change over the course of the four-year period, at least none that was of statistical significance. Per cent cover and species richness were slightly higher in southern areas (Bush Arm, Bear Island) in 2011 relative to 2008, and diversity decreased slightly in central areas (Mica Creek) over the same period, but none of these results was significant (Figure 5-2). Among vegetation communities, per cent cover and species richness in the WB community increased and evenness decreased from 2008 to 2011, while at the same time per cent cover, species diversity and evenness in the BR community decreased (Figure 5-3). Other communities showed little or no change over the same period. There was essentially no detectable change in any of the vegetation characteristics among elevation bands between 2008 and 2011 (Figure 5-4), although there were not enough data to adequately analyze at the lowest elevation band.

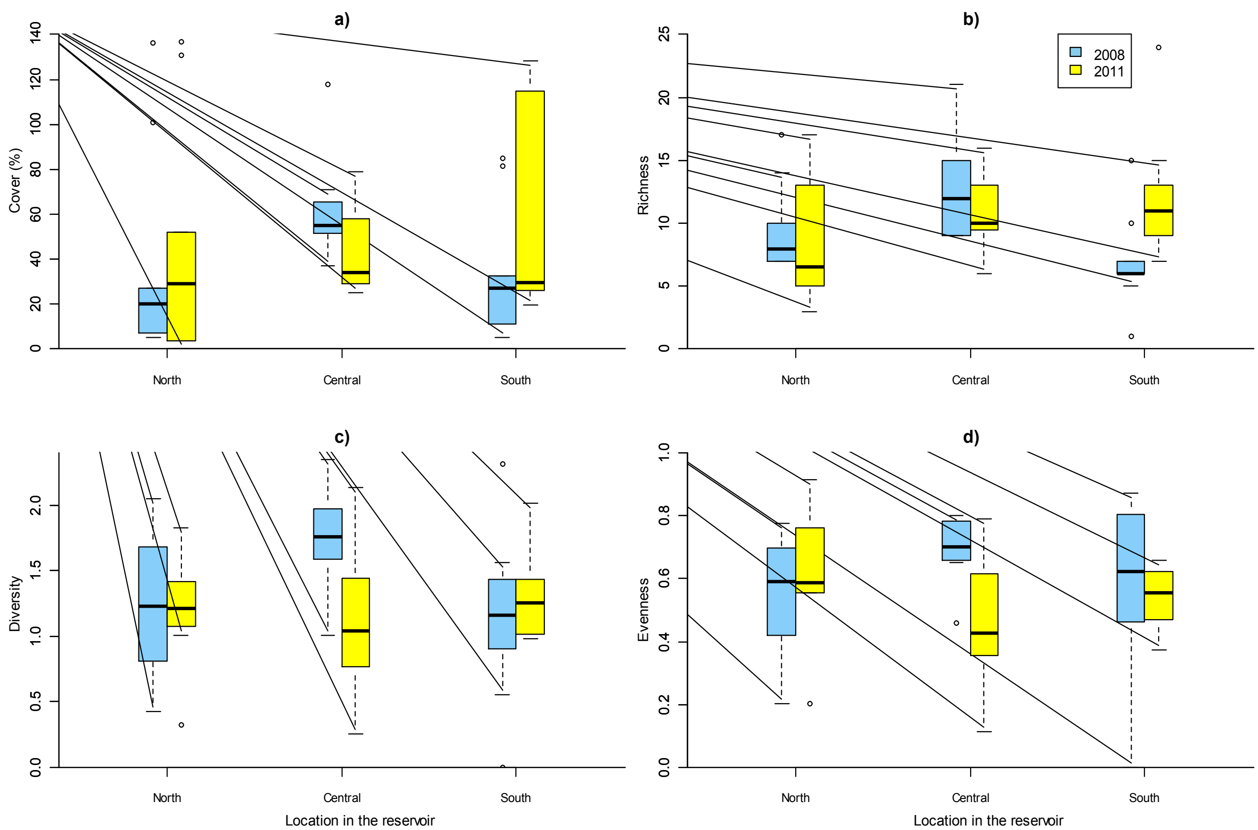


Figure 5-2: Existing vegetation transects sampled in 2008 and plots sampled in 2011 in the same area according to their location in the reservoir, based on (a) cover, (b) richness, (c) diversity and (d) evenness

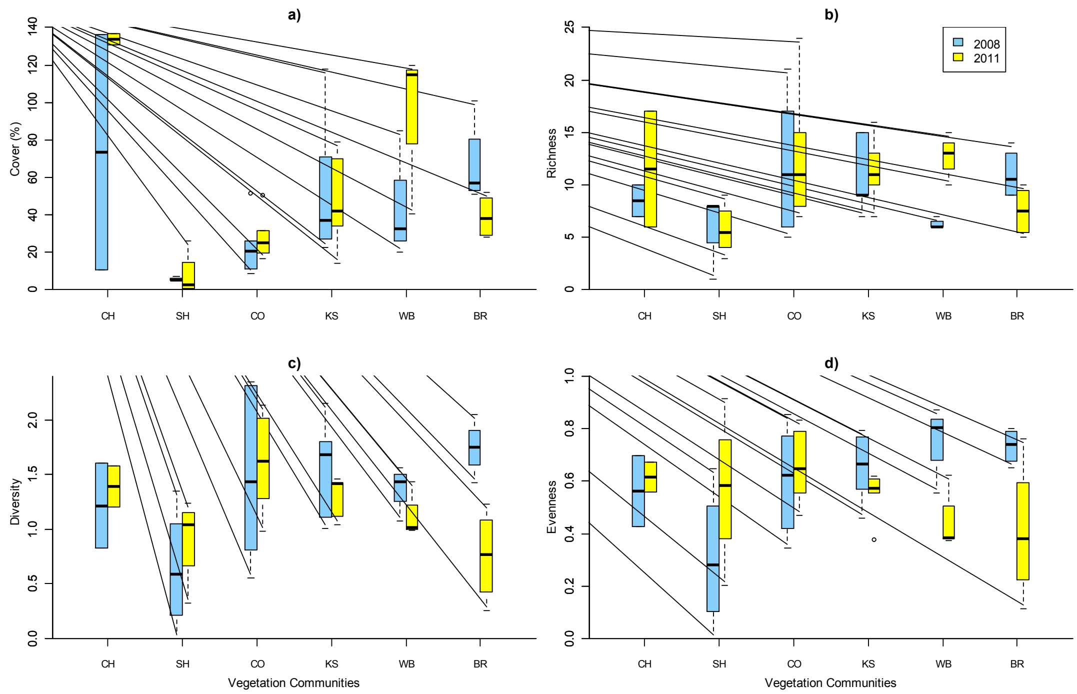


Figure 5-3: Existing vegetation transects sampled in 2008 and plots sampled in 2011 in the same area according to their vegetation communities (see Table 4-1 for community codes), based on (a) cover, (b) richness, (c) diversity and (d) evenness

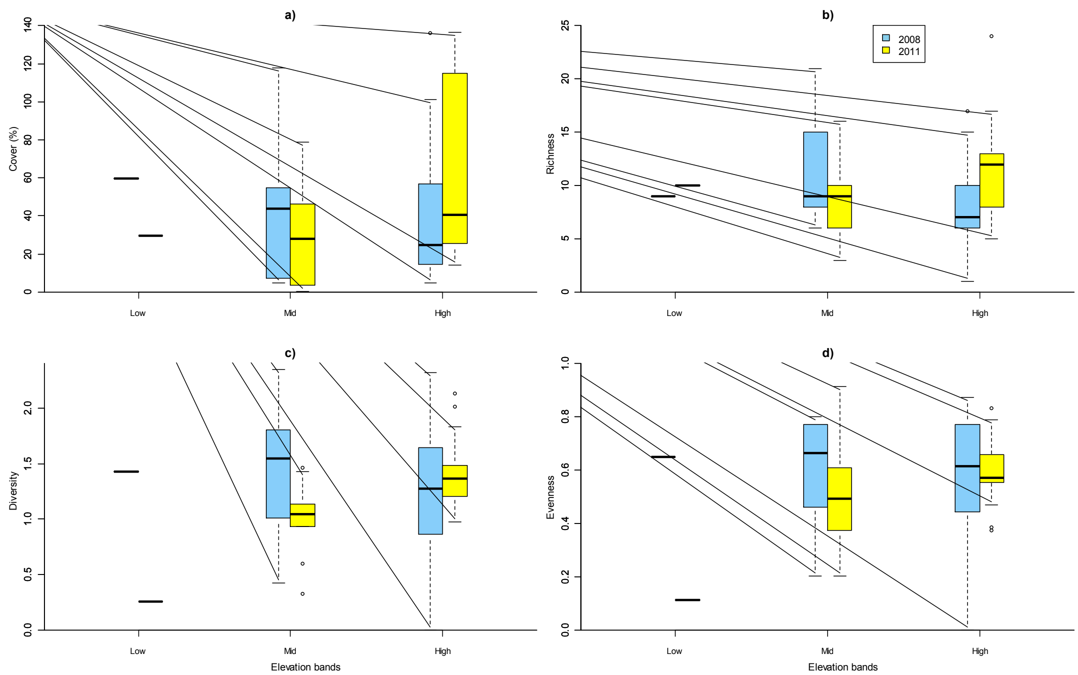


Figure 5-4: Existing vegetation transects sampled in 2008 and plots sampled in 2011 in the same area according to their elevation bands (low = 741 m to 745 m ASL; mid = 746 m to 750 m ASL; high = 751 m to 754 m ASL), based on (a) cover, (b) richness, (c) diversity and (d) evenness

5.3. Revegetated Areas

5.3.1. Summary of Planting Efforts, 2008 to 2011

During the four-year period between the initial revegetation efforts from 2008 to 2011, a total of 69.15 ha of the Kinbasket Reservoir drawdown zone was revegetated by Keefer Ecological Services (Table 5-2). Plug seedling treatments, particularly those involving lenticular (Kellogg's) sedge (*Carex lenticularis*) (alone or mixed with other species), dominated the planting regime throughout this period. 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 (Table 5-2). Only lenticular (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 (ATVS), excavator-planted stakes (EPL) and brush layer (BL) treatments were attempted on one occasion each. Trying to determine the effectiveness of seed trails (ST) in enhancing vegetation growth in the drawdown zone was not possible because natural ingrowth could have been responsible for the appearance of plants that were similar to those in the seed mix. Analyses associated with the revegetation prescriptions were restricted to hand-planted stakes (HPL), hand-planted stakes and plug seedling (HPL/PS), hand seeding (HS) and plug seedling (PS).

Table 5-2: Summary of revegetation efforts of the CLBWORKS-1 planting program between 2008 and 2011, including treatment methods and total number of hectares treated by each 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

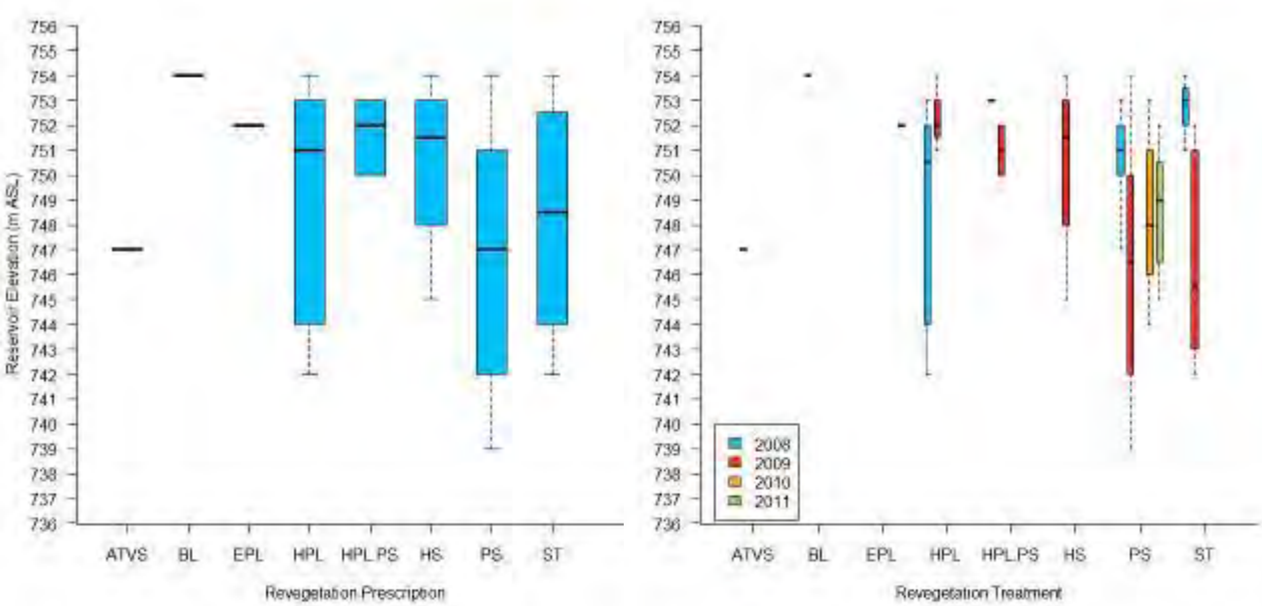
Treatment Method	Prescription	No. Hectares Planted				
		2008	2009	2010	2011	Total
ATVS	Bluejoint machine-spread seed		0.52			0.52
BL	Brush layer		0.01			0.01
EPL	Cottonwood stakes 55 dogwood				1.10	1.10
HPL	Cottonwood livestakes		0.02			0.02
	Cottonwood/dogwood livestakes		0.06			0.06
	Willow	1.60				1.60
	Livestakes	6.28				6.28
HPL/PS	Livestakes/seeding (wetland, buffer mix)	1.38				1.38
	Hand-planted livestakes		0.37			0.37
	Hand-planted livestakes/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

Treatment Method	Prescription	No. Hectares Planted				
		2008	2009	2010	2011	Total
	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
	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**

5.3.2. Elevation of Revegetation Efforts

Revegetation prescriptions were applied to the drawdown zone at elevations ranging from 739 m to 754 m ASL (Figure 5-5a, b). The PS treatment was applied across the greatest elevation range (739 m to 754 m ASL), followed by HPL and ST. More treatments were applied in 2009 than in any other year (Figure 5-5b), and certain treatments (e.g., ATVS, BL and EPL) were attempted in localized areas in only one of the treatment years (ATVS and BL in 2008; EPL in 2011).

Figure 5-5: Elevation distribution of treatments applied in the drawdown zone of



Kinbasket Reservoir between 2008 and 2011 (left) and annually (right). ATVS = ATV seeding; BL = brush layer; EPL = excavator-planted stakes; HPL = hand-planted stakes; HPL/PS = hand-planted stakes and plug seedling; HS = hand seeding; PS = plug seedling; ST = seed trials

5.3.3. Revegetation Effectiveness

5.3.3.1. Survivorship

The survivorship of plug seedlings diminished rapidly following planting (Figure 5-6). Although almost all seedlings were able to survive through their first growing season, the mortality rate increased dramatically following the first winter and the first exposure to extended periods of inundation. For example, survivorship of individuals during the summer in which they were planted was 99.8 per cent but dropped to 53.5 per cent during their second season of growth and to 38.9 per cent during their third season of growth.

Assessment of vigour in the plug seedlings produced results that supported the findings of the survivorship data (Figure 5-6). The percentage of revegetation plots assessed as having overall ―good" vigour dropped from 69.2 per cent for plots that were planted in 2011 to 50.0 per cent for plots that were planted in 2010 to 7.1 per cent for plots that were planted in 2009. Similarly, the number of plots assessed as having “poor” vigour increased from 0.0 per cent for 2011 plots to 42.9 per cent for 2010 plots to 63.6 per cent for 2009 plots.

The survivorship of live stakes was assessed at four different treatment plots, but mortality at each of these plots was 100 per cent (with the exception of a single natural cottonwood seedling at one site, but this was unrelated to the revegetation program). The trends in both live stake and 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 50 per cent after only two years of planting. These trends are expected to continue during subsequent growing seasons as the seedlings are exposed to similar environmental pressures (particularly those associated with reservoir operations), and survivorship rates will likely be lower than those reported here.

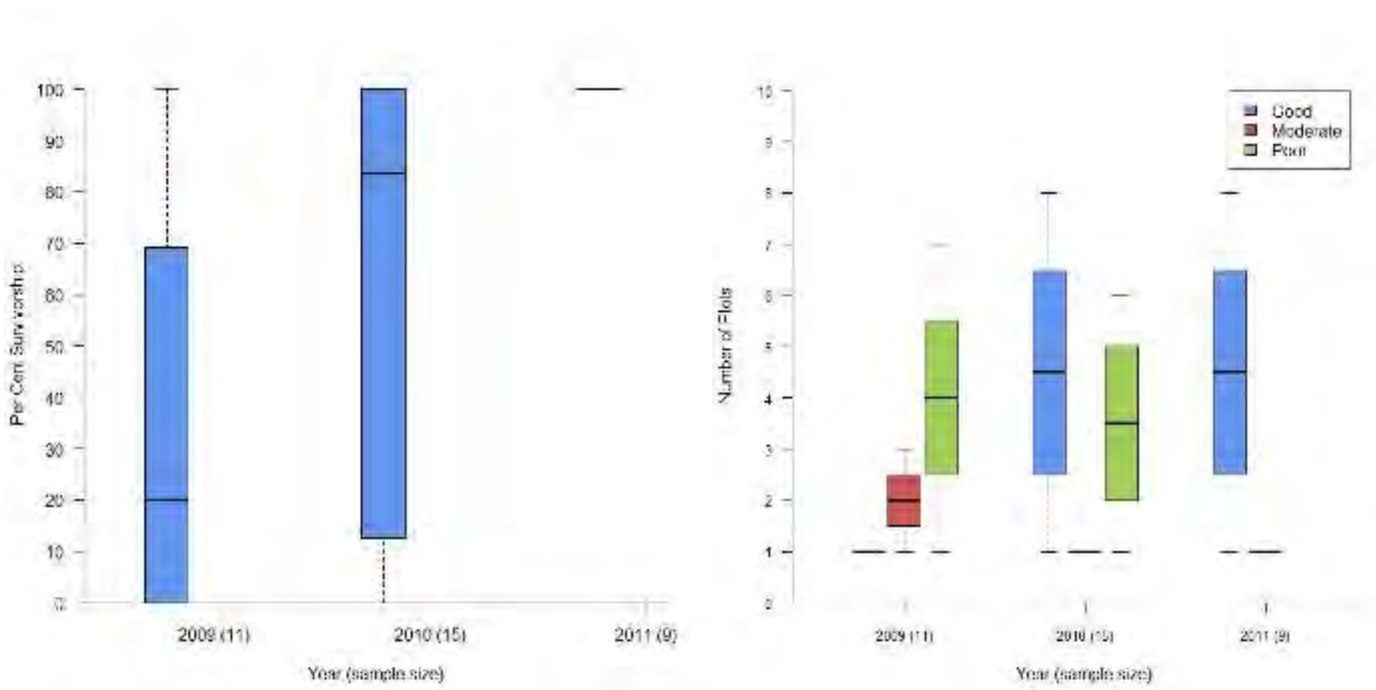


Figure 5-6: 2011 survivorship (left panel) and vigour (right panel) of plug seedlings (PS) planted in 2009, 2010 and 2011. Vigour assessment was based on visual estimates in the field of the health of the overall revegetation plot

Sedge densities declined in both Canoe Reach and Bush Arm, and the survivorship of machine-planted deciduous stakes was low. In some cases, the declines were statistically significant and the causes of the declines were attributed to expected attrition, human-caused habitat alteration, and woody debris removal. Live stake attrition was attributed to mortality, the inability to differentiate between planted and naturally growing seedlings, and the inability to detect seedlings because of the density of competing vegetation.

5.3.3.2. Per Cent Cover

Per cent cover was assessed ~2, 12, and 24 months after planting (for revegetation in 2011, 2010, and 2009, respectively), which provided an indication of the per cent cover in the immediate, one-year, and two-year post-treatment intervals. There were no statistically significant differences between the per cent cover of vegetation in treatment versus control plots in any of the nine vegetation communities that were sampled (Figure 5-8). Similarly, there were no statistically significant differences between per cent cover of vegetation of either existing, treatment or control plots among reaches of Kinbasket Reservoir (north, central, south) (Figure 5-7). However, existing vegetation in the high elevation band had a significantly higher per cent cover and the low elevation band had a significantly lower per cent cover than the other bands (F = 6.2, p = 0.006; Figure 5-9). These differences were not mirrored in the control and treatment plots.

Plots with a mixture of hand-planted stakes (HPL) and plug seedlings (PS) tended to have higher per cent cover (both relative to other treatment types and to control plots) than other treatments, while hand seeding tended to result in lower per cent cover relative to control plots (Figure 5-10); however, none of these differences was found to be statistically significant. The correlations between planting and increase in per cent cover were weak or non existent, with some plots (e.g., Plot 14) showing a noticeable increase in per cent cover following planting, while others (e.g., Plot 32) showed a noticeable decrease in per cent cover (Figure 5-11).

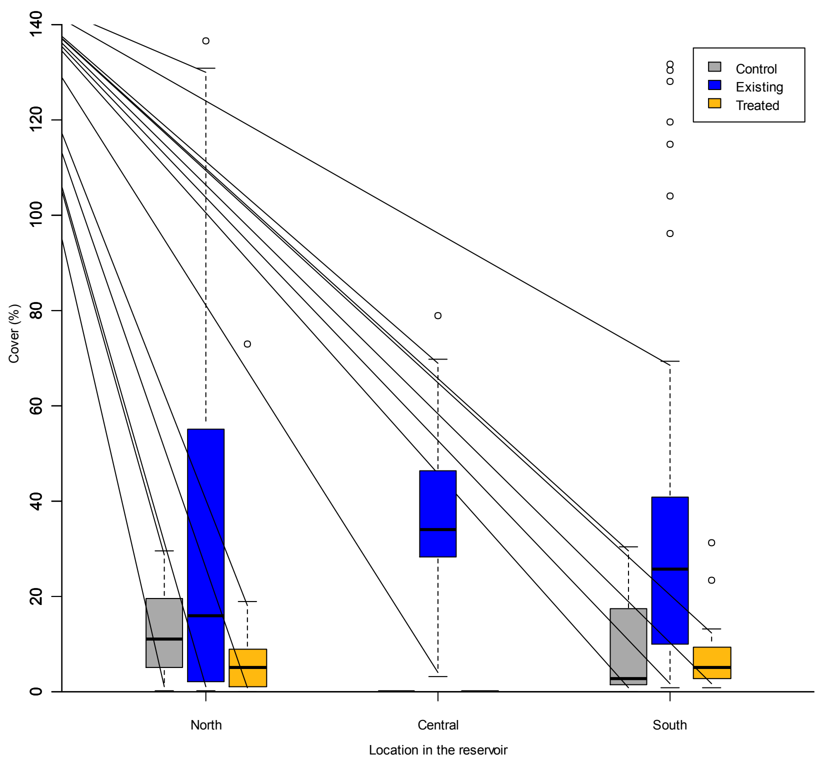


Figure 5-7: Per cent cover of vegetation among different regions of Kinbasket Reservoir. North = Canoe Reach; Central = Mica Creek area; South = Bush Arm/Bear Island

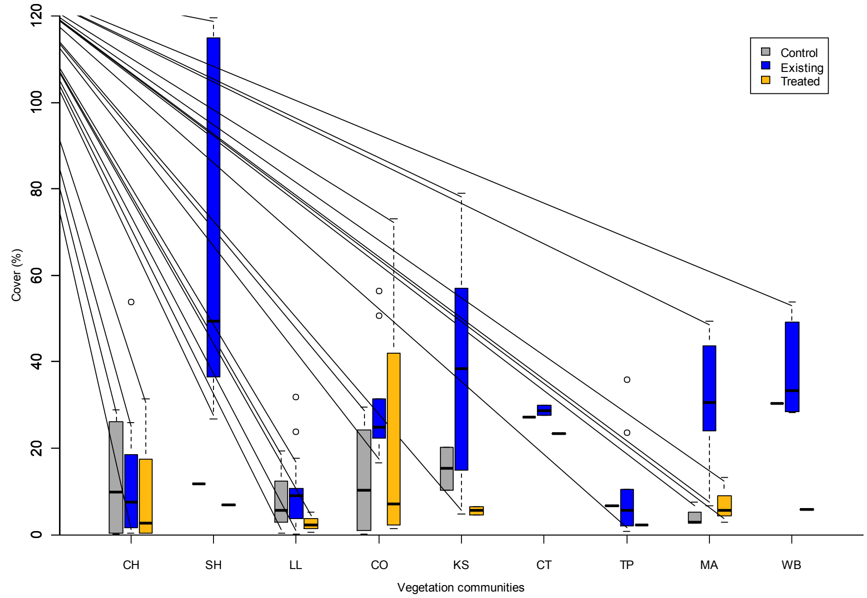


Figure 5-8: Per cent cover of vegetation among different vegetation communities sampled in 2011. See Table 4-1 for vegetation community codes

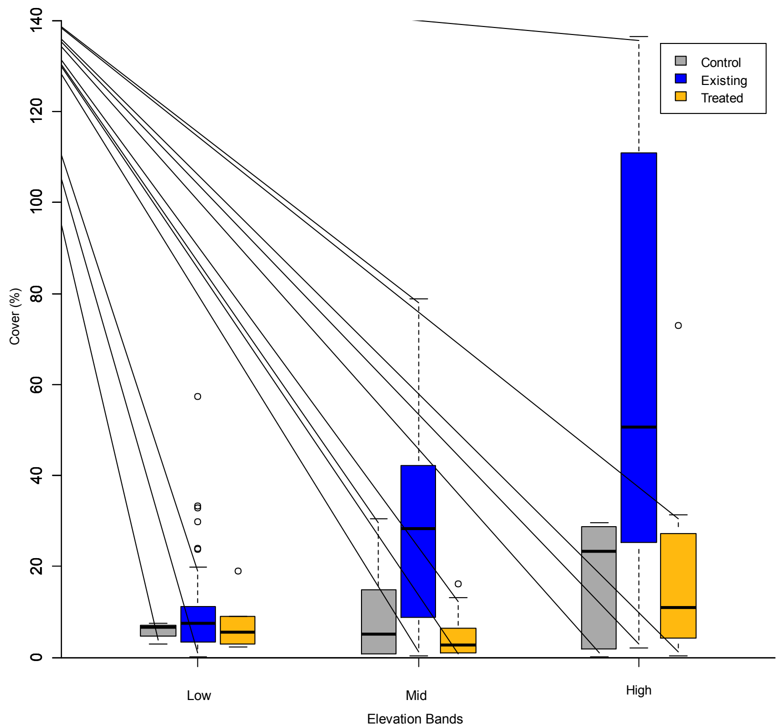


Figure 5-9: Per cent cover of vegetation among elevation bands within the drawdown zone of Kinbasket Reservoir. Low = 741–745 m ASL; Mid = 746–750 m ASL; High = 751–754 m ASL

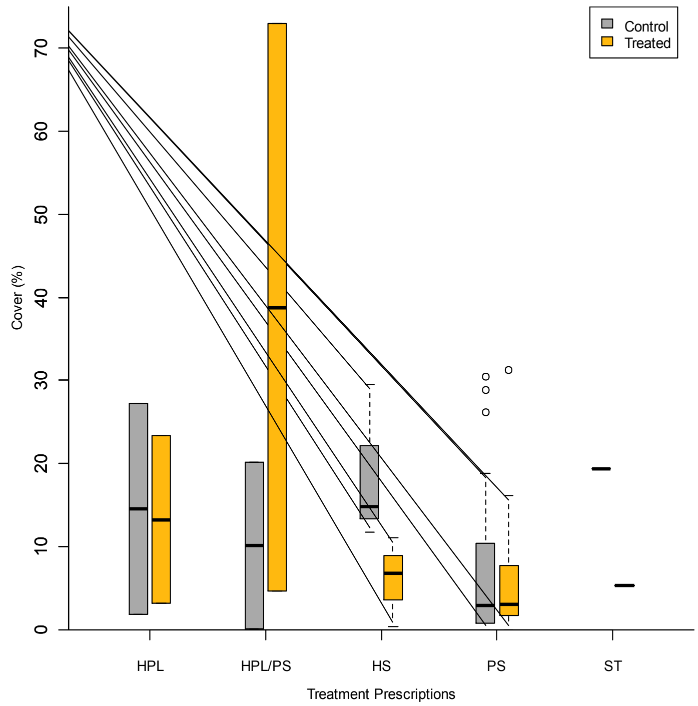


Figure 5-10: Per cent cover of vegetation among different treatment types. See Table 5-2 for treatment codes

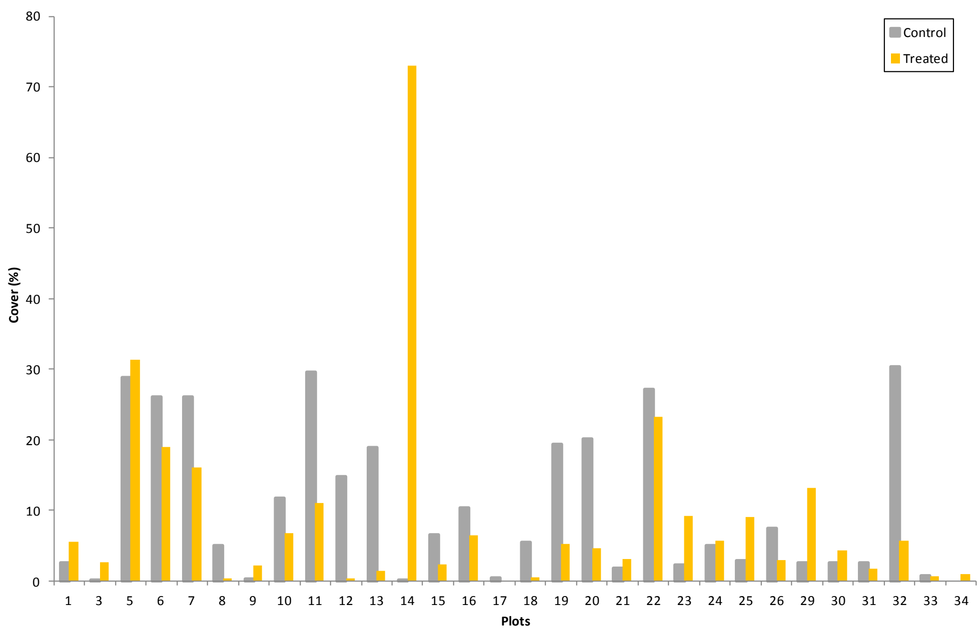


Figure 5-11: Per cent cover of vegetation among treated and control polygons for each plot sampled in 2011

5.3.3.3. Species Richness

There were no statistically significant differences in species richness between treatment and control plots that were sampled in 2011, although the differences among the various vegetation communities were significant (*F* = 13.3, *p* = 0.0000; Figure 5-13). This is an expected result, however, given the inherent differences in the number of species that comprise each vegetation community. Additionally, although higher elevation bands had the highest species richness and lowest elevation bands having the lowest, there were no significant differences between treatment and control plots in any of the three elevation bands sampled (Figure 5-14). There were no statistically significant differences in species richness either among the various treatment types or between treatment and control plots within the treatment types (Figure 5-15). As with per cent vegetation cover, the species richness of treated plots was highly variable relative to control plots: some treated areas exhibited greatly increased species richness relative to the control plots; others exhibited considerably lower species richness (Figure 5-16).

There was a statistically significant difference (*F* = 8.8, *p* = 0.005) in species richness between existing vegetation in plots in the northern part of the reservoir (Canoe Reach) and those in the south (Bush Arm/Bear Island), with southern plots having higher species richness (Figure 5-12); however, there was no significant difference between the treatment and control plots in either of these regions

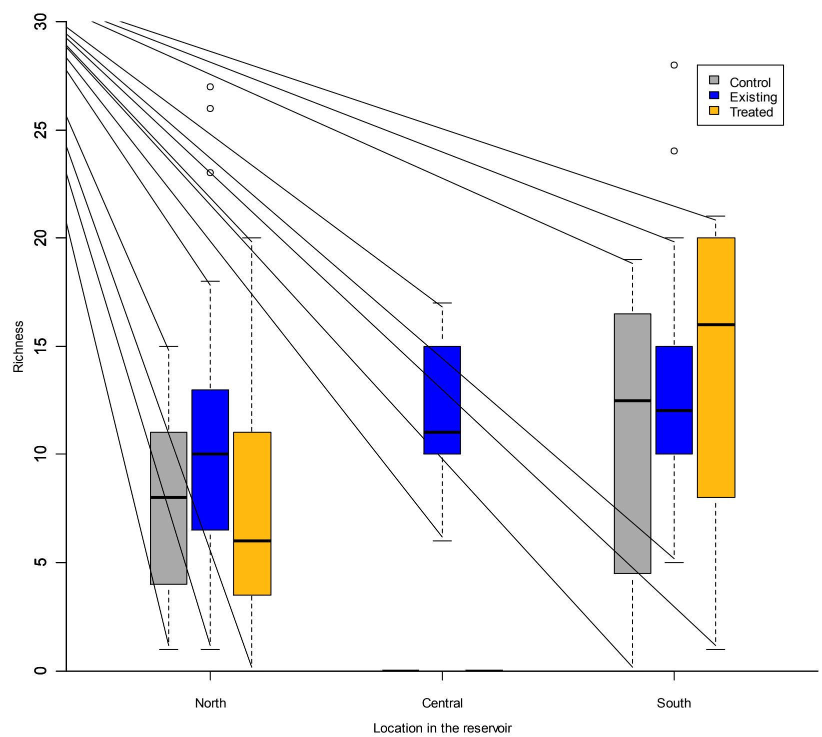


Figure 5-12: Vegetation species richness among different regions of Kinbasket Reservoir. North = Canoe Reach; Central = Mica Creek area; South = Bush Arm/Bear Island

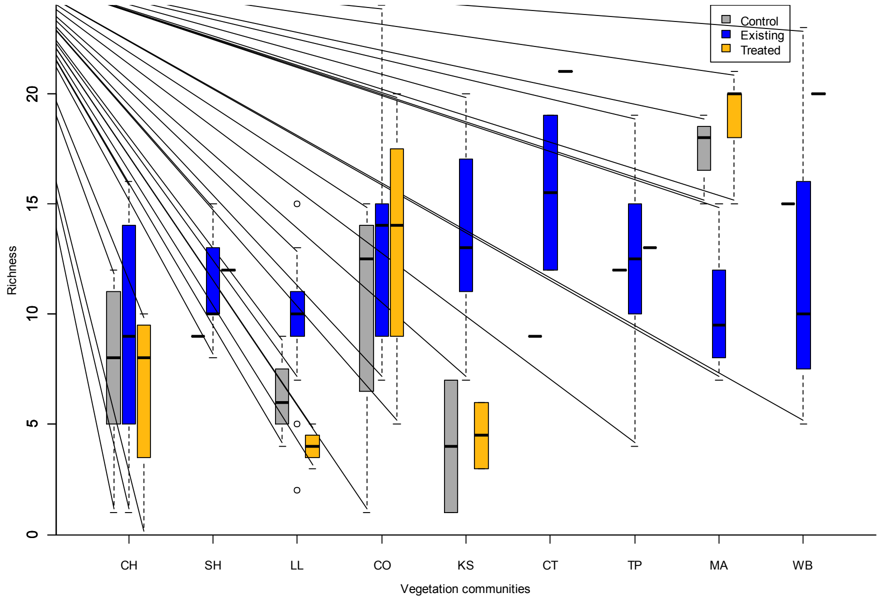


Figure 5-13: Vegetation species richness among different vegetation communities sampled in 2011. See Table 4-1 for vegetation community codes

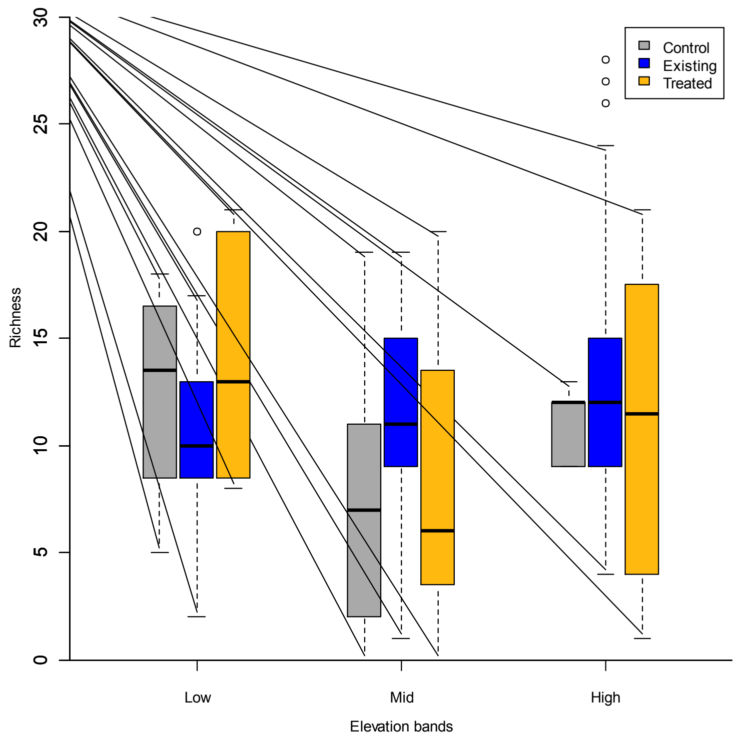


Figure 5-14: Vegetation species richness among different elevation bands within the drawdown zone of Kinbasket Reservoir. See Figure 5-9 for strata ranges

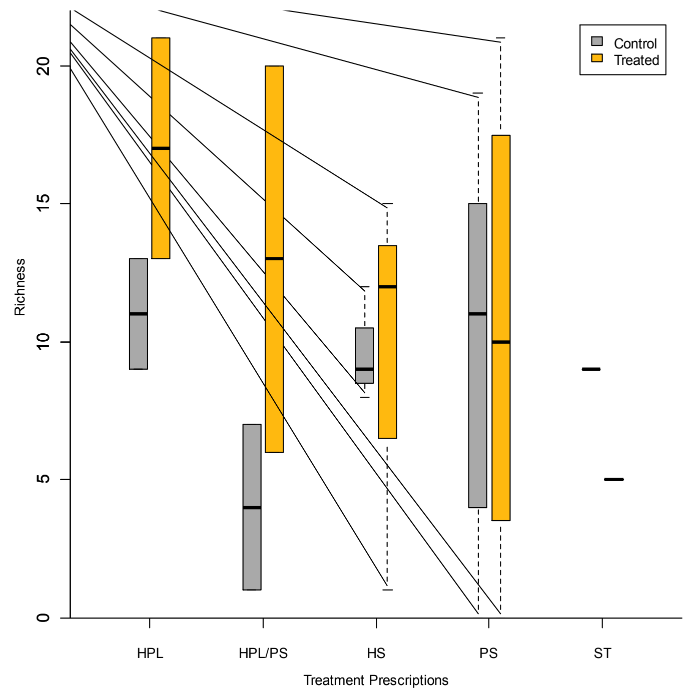


Figure 5-15: Vegetation species richness among different treatment types. See Table 5-2 for treatment codes

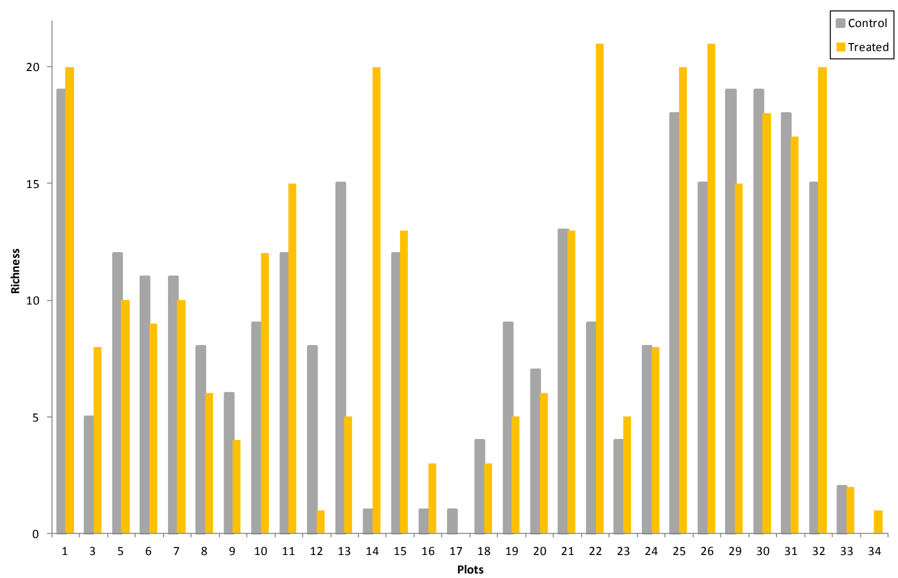


Figure 5-16: Vegetation species richness of treated and control polygons for each plot sampled in 2011

5.3.3.4. Species Diversity

The differences in species diversity (Shannon's Index) largely mirrored those detected in species richness. Plots in the northern portions had significantly lower H' than those from the southern portions of the reservoir (F = 9.2, p = 0.004), but there were no significant differences between treatment and control plots in either of these regions (Figure 5-17). Similarly, although there was a significant difference in species diversity among the various vegetation communities that were sampled in 2011 ($F = 5.8$, $p = 0.001$), there were no significant differences between treatment and control plots in any of these communities (Figure 5-18).

There were no significant differences in species diversity between elevation bands (Figure 5-19), nor were there any significant differences among the various treatment methods (Figure 5-20). Finally, species diversity of treated plots was highly variable relative to control plots: some treated plots had noticeably higher species diversity than adjacent control plots; others exhibited considerably lower species diversity than the control plots (Figure 5-21).

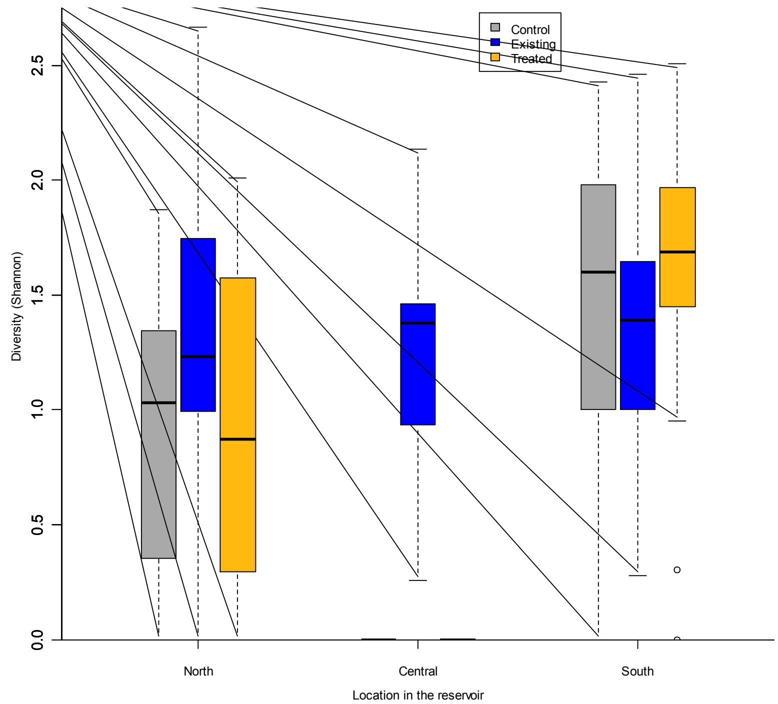


Figure 5-17: Species diversity among different regions of Kinbasket Reservoir. North = Canoe Reach; Central = Mica Creek area; South = Bush Arm/Bear Island

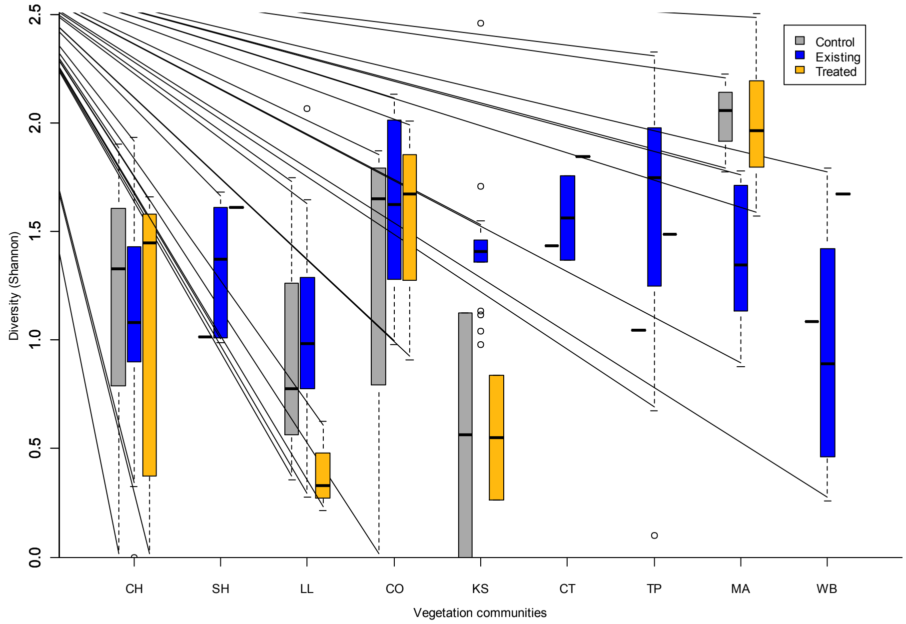


Figure 5-18: Species diversity among different vegetation communities sampled in 2011. See Table 4-1 for vegetation community codes

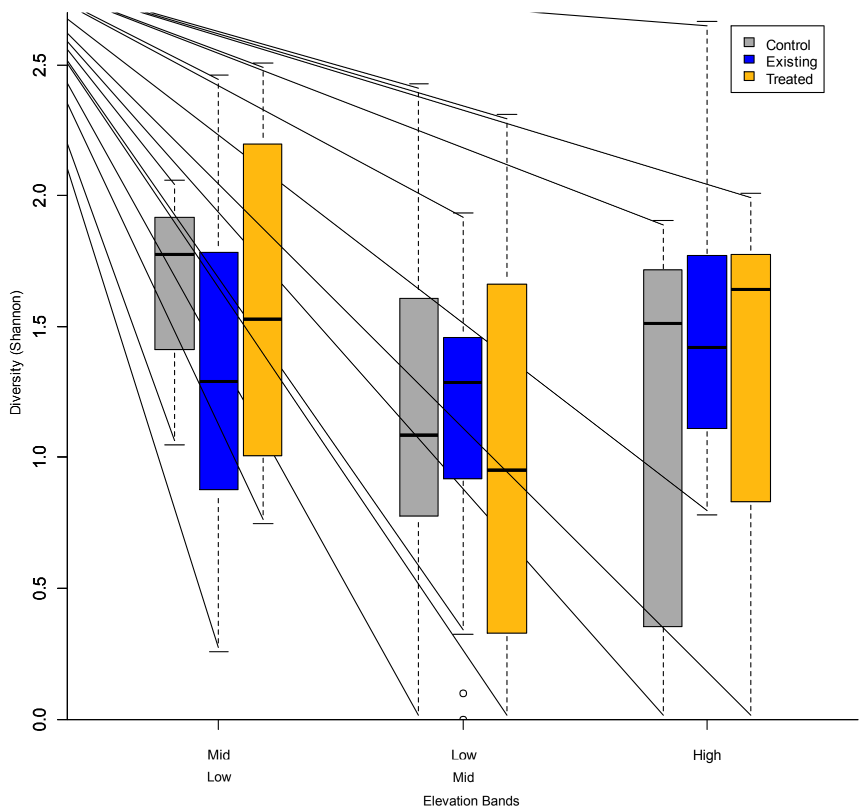


Figure 5-19: Species diversity among elevation bands within the drawdown zone of Kinbasket Reservoir. See Figure 5-9 for strata ranges

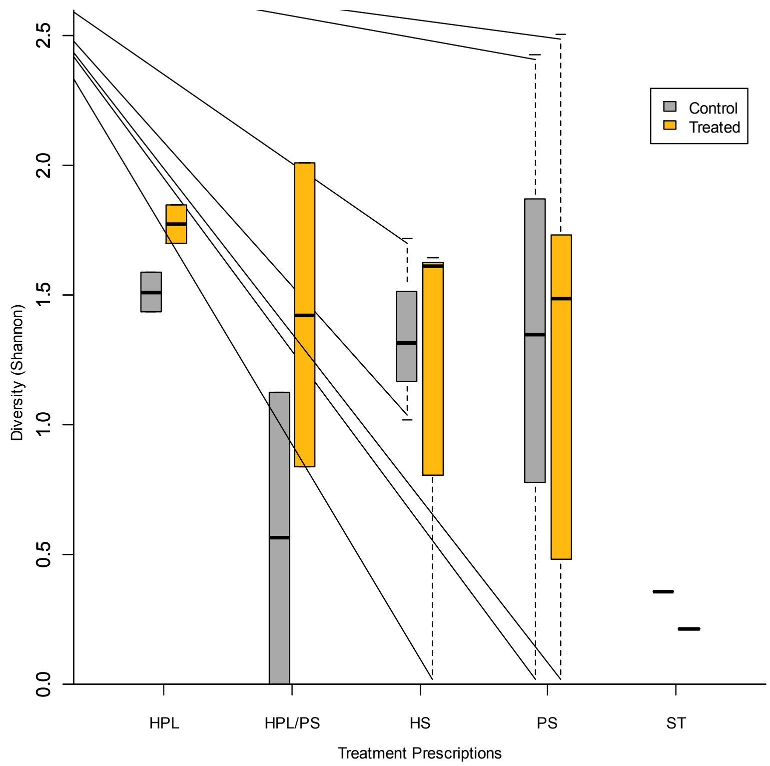


Figure 5-20: Species diversity among different treatment types. See Table 5-2 for treatment codes

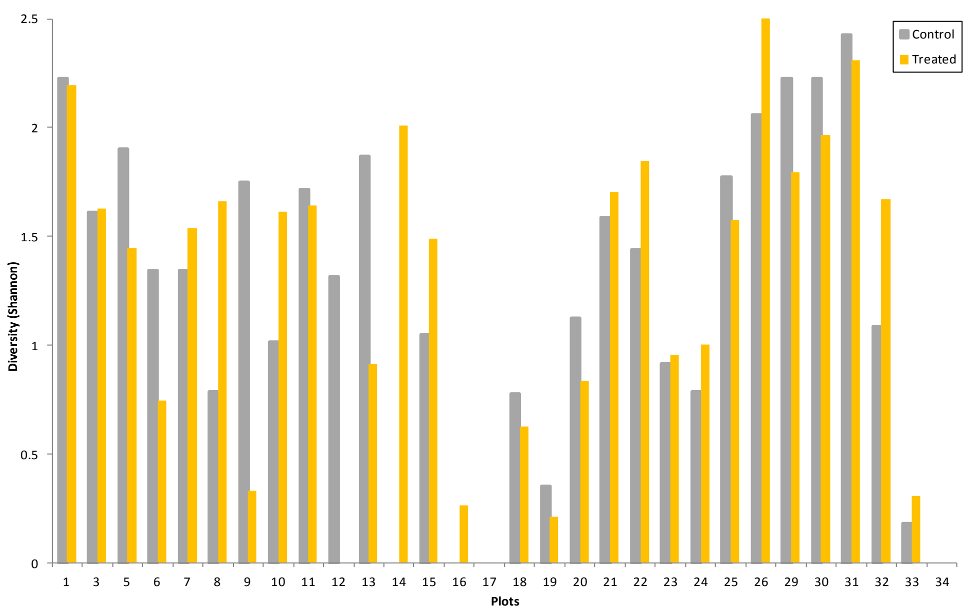


Figure 5-21: Species diversity of treated and control polygons in 2011

5.3.3.5. Exotic Species

The relative cover of exotic versus native plant species did not differ significantly in any of the statistical tests that were performed. This includes tests to investigate differences between regions of the reservoir (north versus south) (Figure 5-22), among vegetation communities (Figure 5-23), between elevational strata (Figure 5-24) and among different treatment types (Figure 5-25). Additionally, there were no significant differences between treatment and control plots.

However, several trends in the data were observed. For example, exotic species contributed slightly higher per cent cover and native species contributed slightly lower per cent cover in northern areas versus southern areas. Also, native species contributed greater cover in upper elevational bands relative to mid and, especially, lower bands. Curiously, however, the cover of native species in treated plots of upper elevation bands was lower than in control plots. Nonetheless, although intriguing, none of these differences are statistically significant.

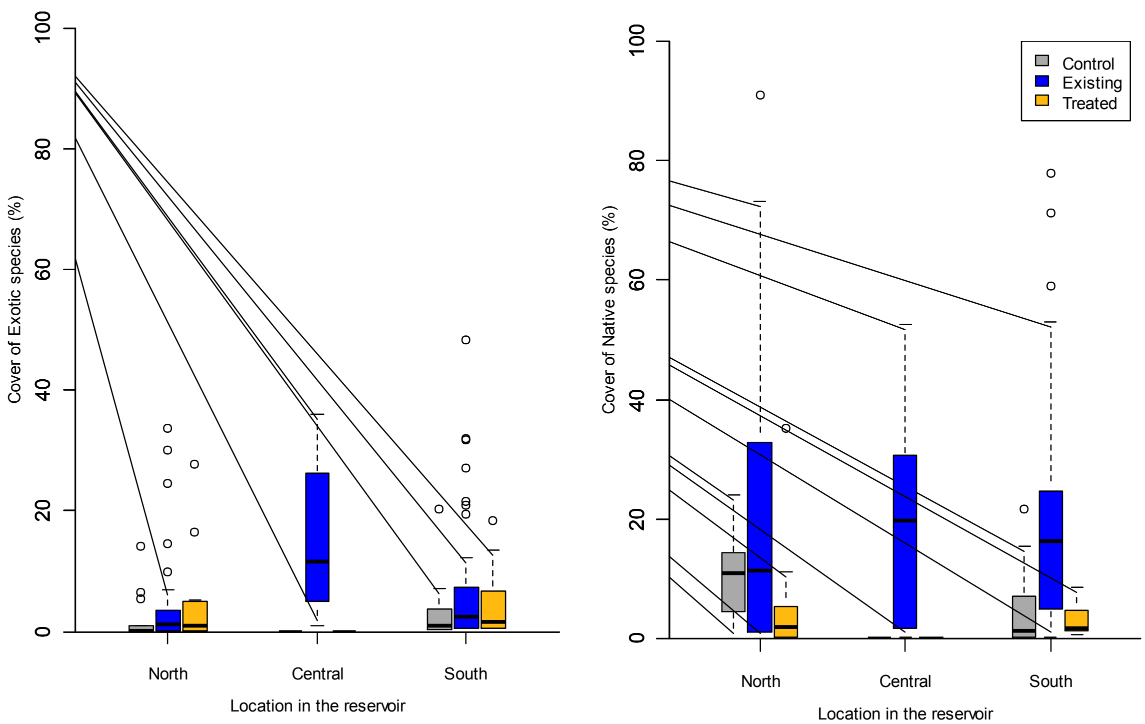


Figure 5-22: Differences in the per cent cover of exotic (left) and native (right) plant species between regions of Kinbasket Reservoir. North = Canoe Reach; Central = Mica Creek area; South = Bush Arm/Bear Island

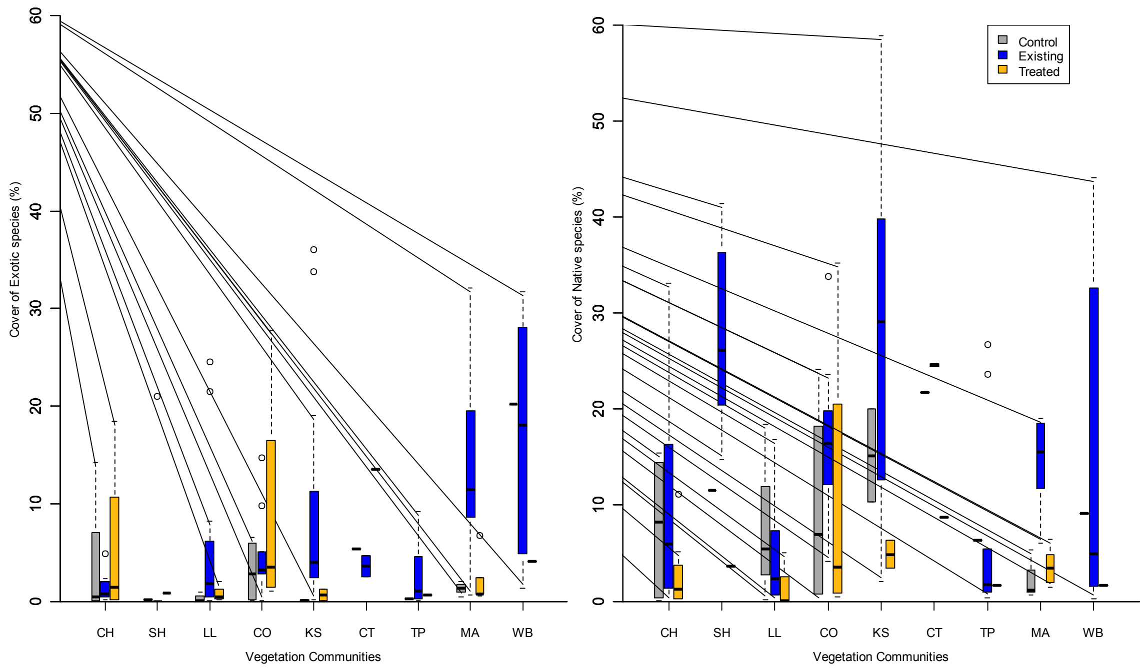


Figure 5-23: Per cent cover of exotic (left) and native (right) plant species between vegetation communities sampled during 2011. See Table 4-1 for vegetation community codes

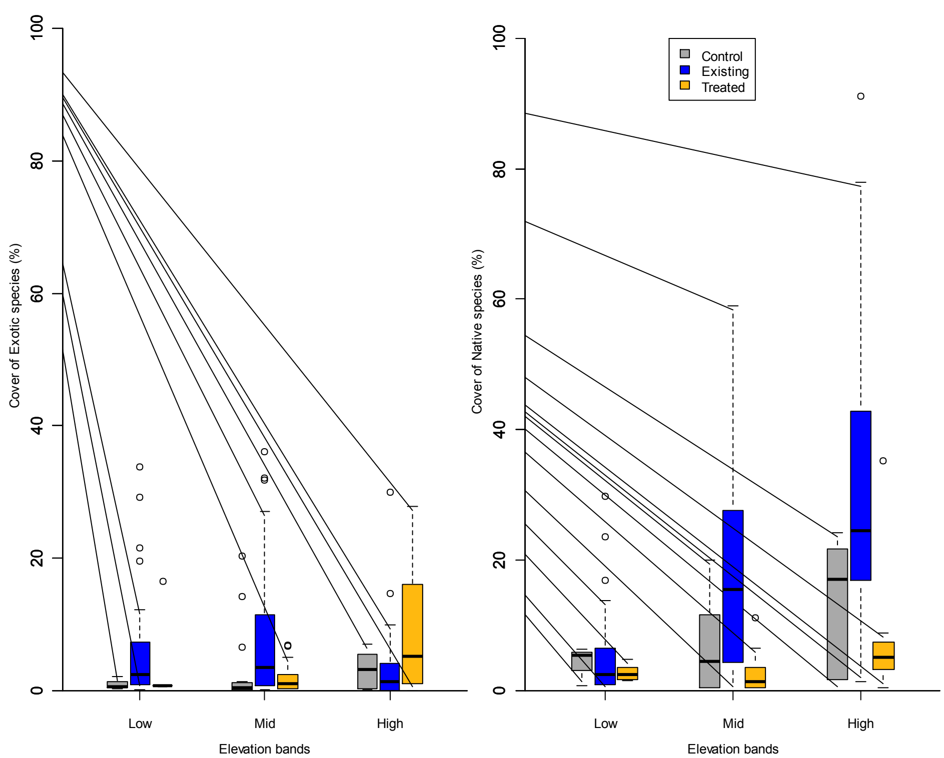


Figure 5-24: Per cent cover of exotic (left) and native (right) plant species between elevation bands. See Figure 5-9 for strata ranges

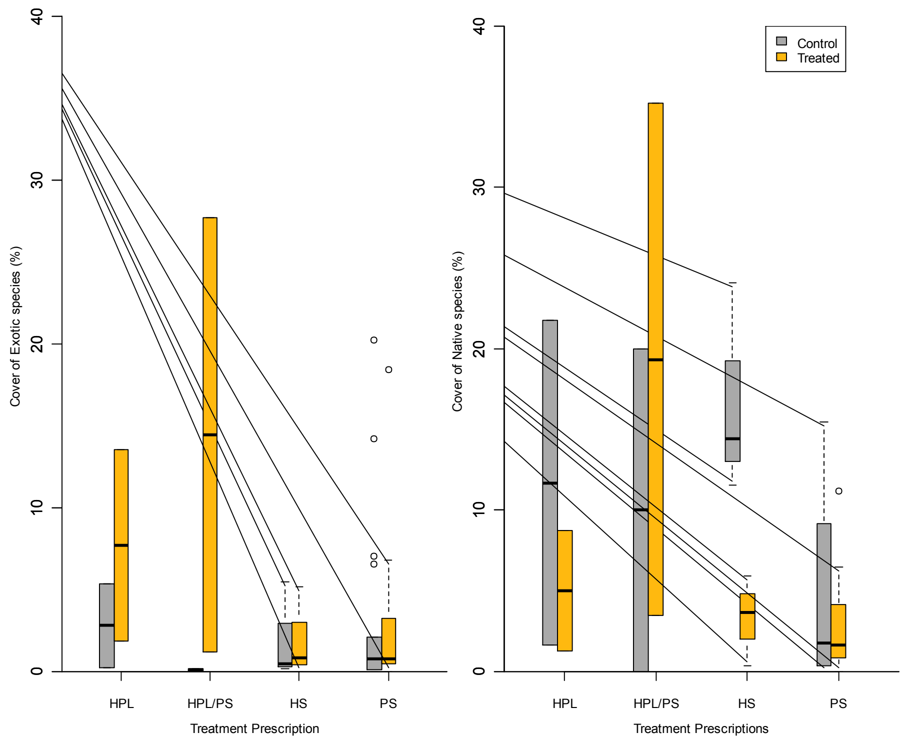


Figure 5-25: Per cent cover of exotic (left) and native (right) plant species between different treatment types. See Table 5-2 for treatment codes

5.4. Laboratory Analyses

5.4.1. Soil Nutrient Analysis

Several nutrients closely associated with plant growth and vigour were assessed (Table 5-3). Magnesium, Phosphorus, and Potassium were all found to be at their highest levels at the lowest elevation bands and their lowest levels in the upper elevation bands. Magnesium levels were much higher in northern portions of the reservoir (Canoe Reach) than in southern portions (Bush Arm), whereas levels of Phosphorus and Potassium were slightly higher in southern areas.

All three nutrients were higher in treated plots than in control plots at the highest elevation bands, but the relative abundances at the middle elevation bands differed between northern and southern reaches of the reservoir. Phosphorus and Potassium levels were higher in treated than in control plots in southern areas, but were higher in control than in treated plots in northern areas. This is likely unrelated to revegetation efforts, however, and instead reflects differences in the natural conditions present among different reaches of the reservoir system.

5.4.2. Vegetation Nutrient Analyses

Vegetation samples were obtained from revegetated areas (treatments) and adjacent untreated controls in both the north and south ends of Kinbasket Reservoir and from each of the three elevation strata (except in the south where data were collected from only the mid and high elevation strata). For the most part, the values obtained for each of the tests were similar between control and treatment areas, and in all cases, the sample size was too small to permit statistical testing (Table 5-4). The high C:N ratios in treated plots at high elevations in northern areas indicate that there is a nitrogen deficiency in these plots that is not reflected in the adjacent control plots.

Table 5-3: Comparison of nutrient levels of soil samples from treatment and control plots in each elevation and geographic strata, data from all revegetation prescriptions combined. "–" indicates value could not be calculated or there were no data

	North (Canoe Reach)																	
Elevation	**741– 745 m ASL**						**746–750 m ASL**						**751– 754 m ASL**					
Treatment	**Control**			**Treatment**			**Control**			**Treatment**			**Control**			**Treatment**		
Test	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**
Buffer pH	6.50	--	1	4.33	3.76	3	2.18	3.38	6	3.30	3.82	4	3.55	5.02	2	2.43	3.82	3
Magnesium, Extractable	98.00	0	2	91.33	16.29	3	86.57	73.71	7	80.00	74.14	4	32.67	0.58	3	38.00	74.14	3
Nitrogen	0.11	0	2	0.08	0.03	3	0.61	0.79	5	1.19	1.68	2	--	--	0	--	1.68	0
Organic matter, walkley-black	4.30	--	1	2.40	1.35	3	15.28	28.19	4	35.70	50.35	2	--	--	0	--	50.35	0
pH	6.00	--	1	5.80	0.26	3	6.55	1.33	6	6.28	1.85	4	6.00	0.99	2	6.20	1.85	3
Phosphorus, Extractable	7.70	--	1	8.17	3.00	3	6.38	7.14	6	2.10	1.46	4	1.35	1.91	2	5.67	1.46	3
Potassium, Extractable	36.00	--	1	45.00	16.52	3	34.83	15.22	6	28.25	5.68	4	18.00	5.66	2	23.33	5.68	3
	South (Bush Arm)																	
Elevation	**741– 745 m ASL**						**746–750 m ASL**						**751– 754 m ASL**					
Treatment	**Control**			**Treatment**			**Control**			**Treatment**			**Control**			**Treatment**		
Test	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**
Buffer pH	--	--	--	--	--	--	0.0	0.0	3	0.0	0.0	3	0.0	--	1	0.0	0.0	2
Magnesium, Extractable	--	--	--	--	--	--	495.0	249.9	4	520.0	336.5	3	90.0	0.0	2	155.0	77.8	2
Nitrogen	--	--	--	--	--	--	1.9	1.5	4	1.8	1.6	3	--	--	0	--	--	0
Organic matter, walkley-black	--	--	--	--	--	--	30.1	25.3	3	27.4	21.8	3	--	--	0	--	--	0
pH	--	--	--	--	--	--	7.1	1.1	3	7.3	0.8	3	8.1	--	1	7.9	0.3	2
Phosphorus, Extractable	--	--	--	--	--	--	4.9	2.6	3	7.8	5.3	3	0.0	--	1	2.5	3.5	2
Potassium, Extractable	--	--	--	--	--	--	22.0	11.1	3	29.3	15.0	3	11.0	--	1	19.0	4.2	2

Table 5-4: Comparison of nutrient levels (per cent dry weight) of vegetation material in treatment and control plots in each elevation and geographic strata, data from all revegetation prescriptions combined. "–" indicates value could not be calculated or there were no data

	North (Canoe Reach)																	
Elevation	**741– 745 m ASL**						**746–750 m ASL**						**751– 754 m ASL**					
Treatment	**Control**			**Treatment**			**Control**			**Treatment**			**Control**			**Treatment**		
Test	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**
Calcium	0.46	--	1	1.16	0.18	3	1.34	0.59	2	1.72	0.25	2	0.45	0.23	2	0.19	--	1
Inorganic carbon	--	--	0	0.35	0.07	3	0.29	0.12	2	0.30	0.18	2	0.14	0.01	2	0.11	--	1
Organic carbon	--	--	0	27.03	9.56	3	38.22	3.08	2	36.75	2.90	2	43.45	1.48	2	43.10	--	1
Magnesium	0.16	--	1	0.42	0.13	3	0.21	0.07	2	0.27	0.04	2	0.08	0.03	2	0.07	--	1
Nitrogen	--	--	0	--	--	0	--	--	0	2.13	--	1	--	--	0	1.08	--	1
Phosphorus	0.30	--	1	0.27	0.16	3	0.19	0.06	2	0.19	0.03	2	0.12	0.08	2	0.11	--	1
Potassium	1.66	--	1	1.71	0.74	3	2.14	0.61	2	2.94	0.30	2	1.33	0.52	2	0.99	--	1
Total carbon	28.10	--	1	27.40	9.50	3	39.40	3.45	2	37.05	3.04	2	43.55	1.48	2	43.95	1.06	2
Total nitrogen	1.79	--	1	1.83	0.85	3	1.46	0.37	2	1.84	0.23	2	1.55	0.77	2	0.77	--	1
C:N	15.70:1	--	1	14.97:1	--	3	26.99:1	--	2	20.14:1	--	2	28.10:1	--	2	57.08:1	--	2

	South (Bush Arm)																	
Elevation	**741– 745 m ASL**						**746–750 m ASL**						**751– 754 m ASL**					
Treatment	**Control**			**Treatment**			**Control**			**Treatment**			**Control**			**Treatment**		
Test	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**
Calcium	--	--	--	--	--	--	0.78	--	1	2.39	0.04	2	0.93	0.55	2	1.59	0.73	2
Inorganic carbon	--	--	--	--	--	--	0.17	--	1	0.58	0.08	2	0.19	--	1	0.47	0.25	2
Magnesium	--	--	--	--	--	--	0.22	--	1	0.81	0.32	2	0.24	0.05	2	0.36	0.21	2
Nitrogen	--	--	--	--	--	--	2.41	1.04	1	--	--	2	--	--	2	--	--	3
Organic carbon	--	--	--	--	--	--	43.60	--	1	39.70	1.13	2	39.20	--	1	41.85	2.05	2
Phosphorus	--	--	--	--	--	--	0.14	--	1	0.12	0.03	2	0.11	0.02	2	0.11	0.07	2
Potassium	--	--	--	--	--	--	1.11	--	1	1.01	0.43	2	1.95	0.52	2	1.26	0.47	2
Total carbon	--	--	--	--	--	--	42.83	0.91	3	40.25	1.06	2	41.60	3.11	2	42.30	1.84	2
Total nitrogen	--	--	--	--	--	--	2.04	--	1	2.25	0.54	2	1.84	0.09	2	1.91	0.41	2
C:N	--	--	--	--	--	--	21.49:1	--	1	17.89:1	--	2	22.61:1	--	2	22.15:1	--	2

5.4.3. Reservoir Operations

The timing, frequency, duration and depth of inundation were assessed to determine if reservoir operations affected vegetation establishment. Each variable was assessed for the growing season, or the period between April 1 and September 30 (*n* = 183 days) each year (Table 5-5). For example, between 2000 and 2006, Kinbasket Reservoir elevations did not exceed 753 m ASL.

During years when revegetation treatments were applied (i.e., 2008 through 2011), Kinbasket Reservoir approached full pool (754 m) in all but one year (2008 [Table 5-5]). The amount of time that the elevation of Kinbasket Reservoir exceeded 741–748 m ASL was greatest in 2009, and the amount of time that elevations exceeded 751 m ASL was greatest in 2011. Vegetation treatments applied in the 741–748 m ASL range in 2009 would have had fewer growing days than those at the same elevations in 2008, 2010 and 2011. Similarly, the number of growing days available to vegetation at elevations above 753 m ASL would have been lower in 2011 compared to 2008, 2009 and 2010.

Table 5-5: Proportion of growing season (April 1 and September 30; n = 183 days) that Kinbasket Reservoir elevations exceeded a particular elevation band (m ASL) from April through September 1997 to 2011. For example, in 1997, elevations between 741 and 742 m ASL were under water for 76.8 of 183 days (0.42 * 183 = 76.8). Shaded cells indicate that the elevation band was not inundated in that year

	Year														
m ASL	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
741-742	0.42	0.62	0.44	0.46	0.30	0.45	0.43	0.40	0.57	0.60	0.55	0.48	0.53	0.46	0.54
742-743	0.40	0.60	0.43	0.44	0.21	0.44	0.40	0.34	0.55	0.59	0.54	0.46	0.51	0.45	0.52
743-744	0.40	0.58	0.42	0.43	0.05	0.44	0.37	0.23	0.54	0.58	0.52	0.44	0.48	0.43	0.51
744-745	0.39	0.56	0.40	0.40		0.43	0.26	0.19	0.51	0.56	0.50	0.42	0.46	0.42	0.49
745-746	0.37	0.54	0.39	0.39		0.42	0.09	0.16	0.50	0.54	0.49	0.39	0.43	0.39	0.48
746-747	0.36	0.52	0.38	0.37		0.40		0.11	0.48	0.52	0.48	0.37	0.40	0.37	0.46
747-748	0.33	0.50	0.37	0.36		0.39		0.07	0.46	0.51	0.46	0.34	0.37	0.35	0.45
748-749	0.31	0.48	0.35	0.30		0.37			0.41	0.49	0.44	0.32	0.34	0.33	0.43
749-750	0.30	0.45	0.33	0.17		0.35			0.35	0.48	0.43	0.27	0.31	0.31	0.42
750-751	0.27	0.40	0.32	0.04		0.32			0.28	0.45	0.42	0.23	0.24	0.27	0.40
751-752	0.26	0.29	0.29			0.23			0.16	0.43	0.40	0.18	0.16	0.19	0.38
752-753	0.24	0.14	0.27			0.06				0.37	0.36		0.06	0.03	0.35
753-754	0.21		0.22								0.19			0.01	0.32

The number of growing days per elevation band was similar between 2008 and 2010, but the number was slightly lower than in these years for most elevation bands in 2009 (Figure 5-26). The number of growing days per elevation band was similar in 2007 and 2011, but there were fewer growing days for elevations above 752 m ASL in 2011. On average, the total number of days that each elevation band was exposed was 22 days less in 2007 than in either 2008 or 2010. For some elevations bands (e.g., 752 m ASL), the number of growing days in 2011 was approximately 60 days less than in 2008, 2009 and 2010. The decrease in the number of growing days coupled with the extended duration of inundation will likely have adverse effects on vegetation treatments applied in the drawdown zone. The magnitude of these impacts will not be assessed until the next scheduled sampling (2013), but it is expected to be similar to the impacts observed when Kinbasket Reservoir was operated to near full pool in 2007. When this occurred, woody stemmed plants, seedling deciduous and coniferous trees, and some vascular plants died (see Hawkes et al. 2010).

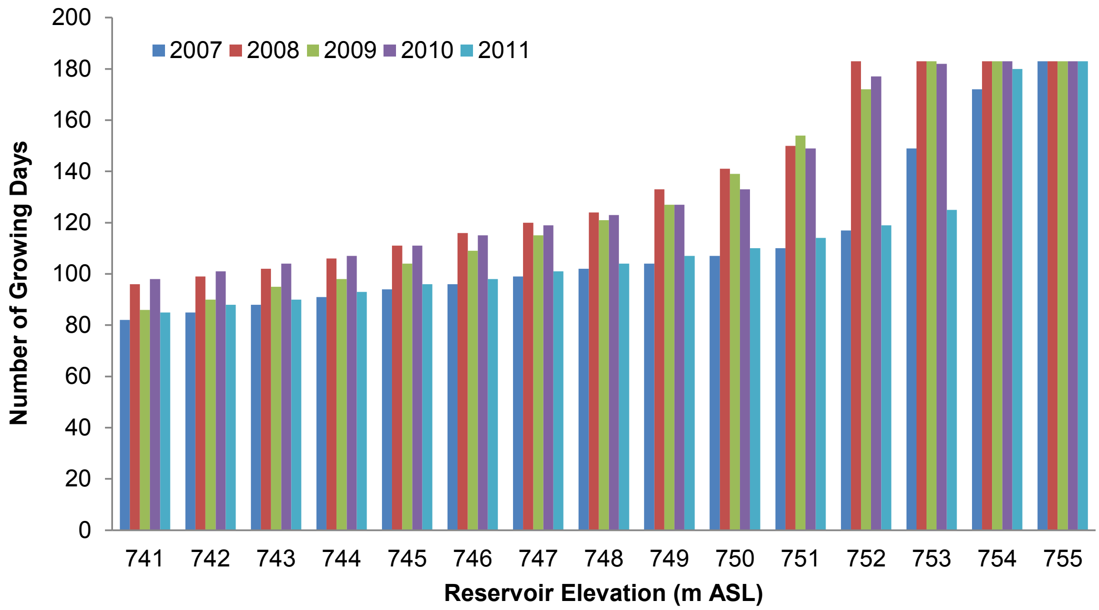


Figure 5-26: Total number of growing days available to each elevation band in the drawdown zone of Kinbasket Reservoir between April 1 and September 30 (*n* = 183 days) in 2007, 2008, 2009, 2010, and 2011

The timing of inundation can affect the establishment and development of vegetation in the drawdown zone of Kinbasket Reservoir. The timing of inundation relative to elevation varied between years, with the reservoir reaching each elevation band almost two weeks earlier in 2007 than in 2008 and 2010 (Table 5-6). In general, the timing and depth of inundation were similar in 2008 and 2010, although the reservoir rose slightly later and reached a lower maximum elevation in 2010 (Figure 5-26, Table 5-6). In all years, all elevation bands were exposed in April and May and during most of June. In 2008 and 2010, all elevations bands were also exposed into early July. Kinbasket Reservoir filled more rapidly in 2011 than in other years, which resulted in fewer growing days for vegetation planted or growing between 741 and 754 m ASL.

Table 5-6: Dates at which each elevation band was inundated per year. "--" indicates elevation band not inundated

Elevation (m ASL)	Year and Date				
	2007	2008	2009	2010	2011
741	Jun 22	Jul 6	Jun 26	Jul 8	Jun 25
742	Jun 25	Jul 9	Jun 30	Jul 11	Jun 28
743	Jun 28	Jul 12	Jul 5	Jul 14	Jun 30
744	Jul 1	Jul 16	Jul 8	Jul 17	Jul 3
745	Jul 4	Jul 21	Jul 14	Jul 21	Jul 6
746	Jul 6	Jul 26	Jul 19	Jul 25	Jul 8
747	Jul 9	Jul 30	Jul 24	Jul 29	Jul 11

748	Jul 12	Aug 3	Jul 31	Aug 2	Jul 14
749	Jul 14	Aug 12	Aug 6	Aug 6	Jul 17
750	Jul 17	Aug 20	Aug 18	Aug 12	Jul 20
751	Jul 20	Aug 29	Sep 2	Aug 28	Jul 24
752	Jul 23 to Sept 26	--	Sep 24	--	Jul 29
753	Jul 28- Aug 29	--	--	--	Aug 4
754	Aug 4-16	--	--	--	Sep 17

Vegetation establishment relative to water depth (as a proxy for wet and dry stress) was assessed from 2007 through 2011. The year 2007 was included because it was the first year since 1999 that Kinbasket Reservoir had been operated to full pool, so the effects of wet stress (increased water depths) on existing vegetation communities and on areas that were revegetated in 2008 were likely to persist into 2008. Differences in water depth were statistically significant among years (Figure 5-27), even when elevation was controlled for (i.e., only water depths at similar elevations). Water depths in 2007 and 2011 were highest in the years assessed. Water depths in 2008, 2009 and 2010 were similar for all elevations, with the exception of some minor differences at elevations above 752 m ASL. The number of days at which each elevation band was inundated in 2008, 2009, and 2011 differed for each elevation band (Table 5-7).

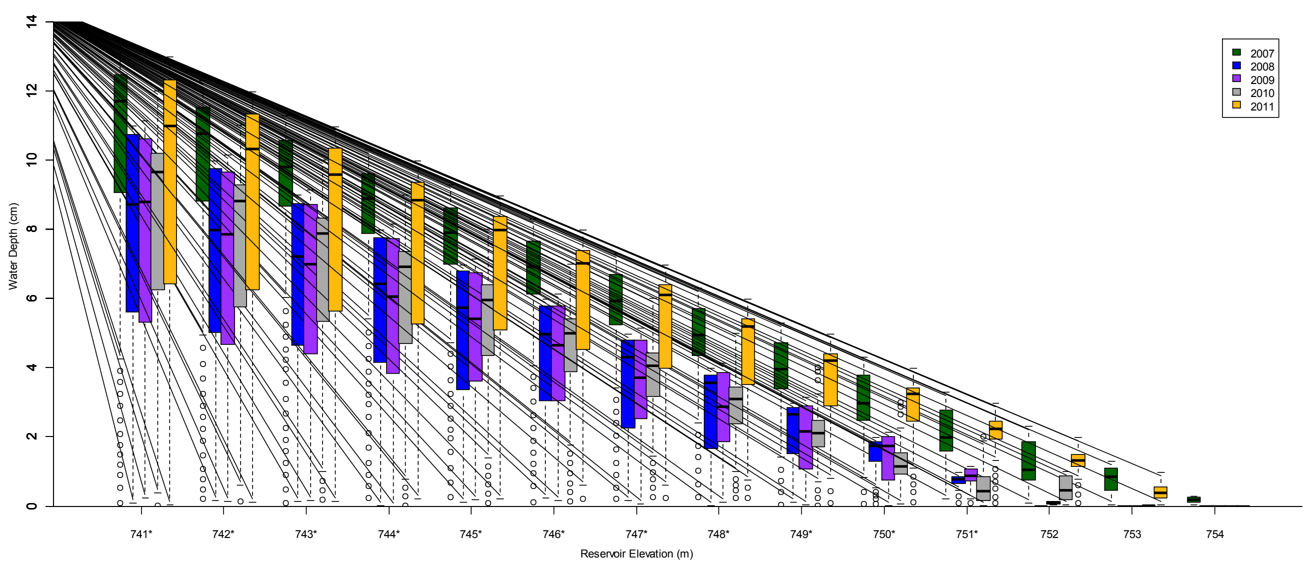


Figure 5-27. Water depths per elevation in Kinbasket Reservoir during the growing season, between 2007 and 2011. Dates when water depth was 0 m are excluded; therefore, sample sizes vary between elevation bands and years. Differences in water depths are statistically significant (at *p* < 0.05) among years for that elevation (elevations > 751 m were not tested)

Table 5-7. Number of days for which water depths were greater than 0 m, per year and elevation band

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

Revegetation prescriptions were typically applied in April or May each year, and as such, the effect of water depth on vegetation establishment and development is best assessed by comparing water depths in the months immediately following treatment. Water depth data for June and/or July were compared among years (2008 to 2011 only) for each elevation band to assess how reservoir elevations immediately following treatment might affect vegetation establishment and development. Water depth was statistically higher in 2011 for elevations between 741 and 747 m ASL (Figure 5-29). In previous years, water depth was similar (which is consistent with results shown in Figure 5-27). This suggests vegetation prescriptions applied in the drawdown zone (in both the north and the south) between 741 and 754 m ASL in 2008, 2009 and 2010 would have had the same level of wet stress, while vegetation prescriptions applied in 2011 will experience a greater degree of wet stress (because they were inundated earlier and the duration of inundation will be longer). The effect of increased wet stress on vegetation in the drawdown zone of Kinbasket Reservoir will not be fully understood until 2012 (the next implementation year for CLMBON-10) and 2013 (when CLBMON-9 is implemented again).

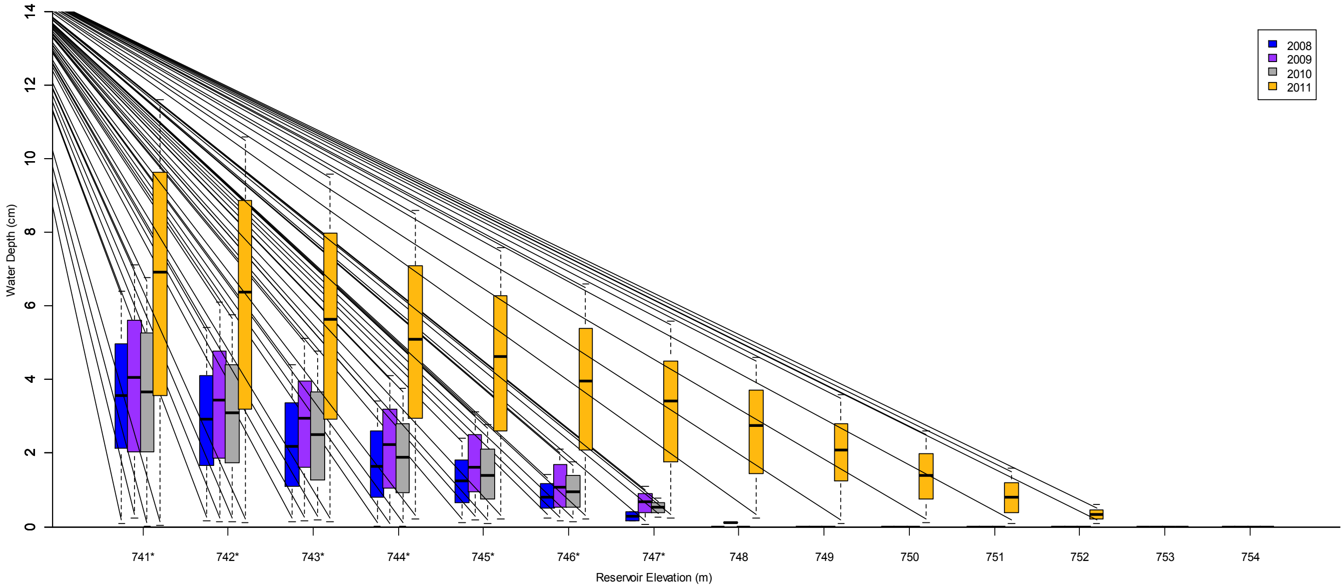


Figure 5-29. Water depths per elevation in Kinbasket Reservoir over time in June and/or July, 2008 to 2011. Data displayed exclude the dates when water depth was 0 m; therefore, sample sizes included vary between elevation bands and years. * differences in water depths are statistically significant (at $p < 0.05$) among years for that elevation (elevations above 747 m were not tested since water depth was 0 m in all years but 2011)

Given the range of elevations that have been revegetated in the drawdown zone of Kinbasket Reservoir (Figure 5-5), and that most treatments were applied between 742 and 753 m ASL, the greatest magnitude of impact on the revegetation areas due to reservoir operations will likely be in the 742 to 748 m ASL range. This is related to the number of days that Kinbakset Reservoir exceeds elevations between 742 and 748 m ASL relative to elevations >749 m ASL (Table 5-7). If Kinbasket Reservoir continues to be operated in a manner consistent with the last five years (Figure 5-1), then every revegetation treatment area will be affected to some degree by reservoir operations, but those in the 742 to 748 m ASL are likely to be affected to a larger degree than those above this elevation (see Hawkes et al. 2010 for more on changes to vegetation communities in this elevation range).

The duration of inundation did not vary over time, with most elevations inundated once during the growing season (April through September) in 2007, 2008, 2009 and 2010. The exception to this is that in both 2008 and 2010, Kinbasket Reservoir did not exceed elevations above 752 m ASL, and in 2009, the elevation of Kinbasket Reservoir did not exceed 753 m ASL. There are years when Non-Treaty Storage Agreements (NTSA) are implemented, which may explain why reservoir elevations in 2007 and 2011 were higher than in 2008, 2009, and 2010. The relationship between the frequency and NTSA on revegetation effectiveness should be considered.

6.0 DISCUSSION

All management questions described for the CLBMON-9 monitoring program were addressed, or in some cases, will be addressed once a larger data set is available. Table 6-1 summarizes the management questions and hypotheses associated with CLBMON-9, and it includes a brief summary of the data required, current status of the program, and (key) preliminary results associated with each management question. An indication of whether or not we think the management question will be addressed by this monitoring program and the associated field and analytical methods is also provided.

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 (quadrats), lab data	Ongoing; many revegetation polygons were characterized in 2011	No significant differences in quality and quantity of vegetation between treated and untreated plots, at least at the landscape scale
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}			Yes	Field data (survivorship plots)	Ongoing; many revegetation polygons were characterized in 2011	Steep decline in survivorship of sedge plugs each year following 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}	Yes	Time series data (minimum of 5 years)	Approaching ability to determine these relationships, but require at least two more years of data	Specific data on the relationships between revegetation effectiveness and reservoir operations will be forthcoming
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}	Yes	Field data (quadrats, survivorship plots), lab data	Ongoing; many revegetation polygons were characterized in 2011	Widely variable results among individual plots and treatments, with no significant differences among treatments
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}	Yes	Review of CLBMON-10 annual reports, time series data	See Hawkes et al. (2010) for most recent assessment	See Hawkes et al. (2010) for most recent assessment, including mapping of vegetation communities. Unclear as to whether the benefits are greater than those associated with natural colonization.

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}	Yes	Review of existing literature, past reports, and current status of the revegetation program	A review of the effectiveness of the current revegetation program, including opportunities for additional improvements, is presented in this report	Several opportunities exist for improvements to the revegetation project in 2011, as discussed in Sections 6.0 and 8.0 of this report

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.

6.1. Existing Vegetation

Existing vegetation was sampled alongside treatment and control plots. More detailed analyses of the existing vegetation of Kinbasket Reservoir, including descriptions of the plant communities and maps of their distributions, are available in Hawkes et al. (2010). Overall, differences in existing vegetation were relatively minor and largely related to latitude (i.e., which reach of the reservoir that the vegetation was growing in) or the site localized conditions.

6.2. Summary of Revegetation Effectiveness

Revegetation ecology in reservoir drawdown zones is an emerging field; therefore, there is relatively little literature available to guide revegetation efforts (Abrahams 2006, Keefer et al. 2008). As a result, each revegetation project must rely on both the existing literature as well as on a more generalized understanding of restoration principles, such as plant science, soils, geomorphology and horticulture, to help guide the project (Keefer et al. 2008). More than most habitats, reservoir drawdown zones provide particularly challenging conditions within which to establish plant communities through revegetation efforts. This is due to a combination of factors:

- the prolonged (but not continuous) seasonal inundation of most of the zone;
- the hydrologic cycle, in which the reservoir is held at low water during the spring and then the water gradually increases throughout the summer (opposite of the schedule that most plants are adapted to);
- 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.

Reservoir drawdown and reflooding thereby alter successional processes, creates continued disturbance in the system, and affects physical and chemical parameters of the substrates (Abrahams 2006). These factors, in combination with the scant existing literature on the revegetation of drawdown zones, have necessitated a trial-and-error program in which a number of revegetation treatments are applied through the study. In this way, the most effective and successful treatments can be determined and subsequently applied more widely throughout the reservoir.

A major component of this report is an assessment of the overall effectiveness of revegetation efforts within the drawdown zone of the Kinbasket Reservoir during the first four years of the program (2008–2011). To date, the success of the various revegetation treatments has been highly variable, with some plant communities establishing quickly while others have struggled or, in many cases, been completely unsuccessful. Revegetation programs had few significant impacts on the distribution of plant communities in the drawdown zone of Kinbasket Reservoir. For example, no statistically significant difference was detected in the per cent cover of vegetation between treatment and control plots in any of the nine vegetation communities that were sampled. In all but one of these nine communities (MA), the mean per cent cover of the vegetation quadrats was actually higher in control plots than in the treated plots, although this result was not statistically significant.

Analysis of other vegetation variables, such as species richness, species diversity, and overall cover of exotic species showed similar trends to per cent cover, with little or no statistically significant differences between treatment and control plots. Survivorship assessments showed a high mortality of sedge plugs during each year following planting, through at least the first two years of establishment, with survivorship of sedge plugs dropping from nearly 100 per cent during the year of planting to approximately 39 per cent two years later. The survivorship of live stakes has fared even worse: five of the six sites that received live stake treatments in 2009 and 2010 recorded mortality in excess of 60 per cent (three exceeded 80 per cent) in late 2010 (Keefer et al. 2011). The survivorship of deciduous seedlings, however, has been more successful than live stakes (Keefer et al. 2011): mortality at all three sites in Bush Arm has been equal to or less than 50 per cent.

Although still relatively early in the planting program (the planted communities have not yet reached their full development), these results suggest that the effectiveness of current revegetation efforts is poor and the vegetation communities are struggling to become established. There are several reasons for the relatively poor performance of the revegetated sites in certain areas of the drawdown zone. They include impacts caused by the routine removal of accumulated woody debris and impacts caused by humans (ATV use). Across the entire reservoir, the limited success of the revegetation program can also be attributed to reservoir operations; however, the magnitude of the reservoir-related impacts will not be known until 2012. There are also aspects of the revegetation program that may have contributed to the poor performance of the revegetation treatments in the drawdown zone of Kinbasket Reservoir. These are discussed below.

6.2.1. Pre-planning

Effective preliminary planning is a critical component of any revegetation or restoration program. Planning helps ensure that project objectives are clearly understood, benchmarks for success are defined, effective methodologies are in place, and protocols can be adapted if benchmarks for success are not being met.

Revegetation of the drawdown zone of the Kinbasket Reservoir (CLBWORKS-1) was designed to address the following environmental and social objectives:

1) maximize vegetation growth in the drawdown zone;
2) provide benefits to littoral productivity and wildlife habitat through increased habitat diversity;
3) increase the diversity of native plants, particularly those of interest to First Nations; and
4) provide increased protection for known archaeological sites, where possible.

The first three objectives, which pertain directly to the distribution and abundance of vegetation within the drawdown zone, are considered the foremost objectives: they are the focus of this effectiveness assessment. Keefer Ecological Services developed strategies that would address each of these objectives through the planting of seedlings and live stakes, hand seeding, and fertilizer treatments (Keefer et al. 2008). Programs were initiated in 2008 as part of CLBWORKS-1 to monitor the survivorship of seedlings and live stakes as well as the success of hand seeding and fertilizer trials, and these were carried on throughout subsequent years. In addition, CLBMON-9 similarly monitored these parameters independently, particularly through the assessment of species diversity, vegetation cover and foliar nutrient analysis within each of the treatment strata. Thus, monitoring of the success of various revegetation treatments throughout Kinbasket Reservoir has been thorough and continuous throughout the entirety of the program to date, and has allowed for a direct assessment of the status of these parameters relative to untreated sites adjacent to the treated polygons.

Despite the monitoring programs that are in place, few benchmarks for success were established during the early stages of the revegetation program; therefore, it is now difficult to ascertain if current conditions are meeting targeted levels of species diversity, abundance and vigour. Overall trends in each of these factors within the treated polygons have been detected and reported (e.g., Keefer et al. 2008, 2010, 2011, Yazvenko 2008*a*, 2009), but specific references to targets or benchmarks have been largely lacking in each of these reports. For example, no mortality benchmarks were established at the start of the planting program for seedlings and live stakes, so current rates of mortality are difficult to relate to expected values (although the current mortality rates, which approach 100 per cent, would not have been acceptable under any benchmarks). Long-term targets and interim benchmarks are an important consideration for monitoring because they allow the trends that are present to be assessed relative to an ideal condition that would be described during the initial identification of the benchmarks; therefore, the changes that occur can be given not only a direction but also a relative value. This component appears to have been largely overlooked during the pre-planning stages of CLBWORKS-1, and this oversight has been carried throughout the subsequent years of the project.

A number of other factors need to be addressed during the earliest stages of a project such as CLBWORKS-1; without attention to each of these, it can be difficult to effectively carry out a project during its latter stages. Abrahams (2008) provides a summary of important considerations during preliminary stages of a revegetation program, some of which appear to have been overlooked during the planning for CLBWORKS-1. Table 6-1 presents these factors and outlines how each was addressed for CLBWORKS-1. In this case, 25 of 31 planning questions, as presented in Abrahams (2006), were addressed during the early stages of the CLBWORKS-1 program.

Table 6-2: Checklist for project planning of vegetation establishment schemes in drawdown zones. Adapted from Abrahams (2006).

Planning Question	Was this addressed in CLBWORKS-1?	How was this addressed in CLBWORKS-1?
Ecological Factors		
What are the ecological factors that will determine succession and stability?	Yes	All environmental factors (e.g., hydrologic regimes, soil quality, existing communities) that would apply were investigated and described in Keefer et al. (2008).
Physical Conditions		
Is the substrate type and configuration suitable?	Yes	Soil analysis was conducted at all sites prior to planting, and included both physical and chemical attributes of the soil (Keefer et al. 2008).
What are the existing levels of nutrients and contaminants in the substrate?	Yes	Soil analysis (see above) (Keefer et al. 2008)
What are the shoreline gradients and water depths?	Yes	Shoreline gradients were obtained from topographical maps of the drawdown zone and from on-site evaluation of the slope and aspect (Keefer et al. 2008). Potential year-to-year variation in water depths was obtained from analysis of previous reservoir activity relative to the elevation bands of the drawdown zone.
Will there be frost and erosion problems during germination?	Partially	This was alluded to in Keefer et al. (2007), but the extent to which this factored into site selection is unclear.
Can wind and wave action be reduced?	No	This does not seem to have been taken into account, although there would be few options available to reduce erosion from wind and waves.
Will altitude limit plant growth?	No	N/A. These are low-elevation sites with few altitudinal restraints on plant growth, particularly for locally sourced plants.
Will large woody debris accumulate at the site?	No	Does not seem to have been addressed.
Hydrological Conditions		
What is the depth, duration and timing of flooding/drawdown?	Yes	This was thoroughly addressed in that specific treatment prescriptions were provided for different elevation bands (and inundation periods) in the drawdown zone.
Are there areas of eulittoral that remain damp through seepage?	Yes	This was evident from analysis of the vegetation community maps presented in Hawkes et al. (2010)
What are the levels of wave action and currents?	Yes	This was taken into account during the site selection process (i.e., Esplanade Bay [Site 103] was cited as having unusually high exposure to wind and waves as well as the associated erosion issues) (Keefer et al. 2008).
Can water level be controlled during the establishment period?	Yes	Uncertainty in future annual reservoir drawdown and flooding events was taken into account (Keefer et al. 2008).
What is the long-term management plan for water level control?	No	This was not specifically discussed nor presented.
What are the nutrient levels and water quality parameters?	Yes	Soil analysis was completed.
Biological Factors		

Planning Question	Was this addressed in CLBWORKS-1?	How was this addressed in CLBWORKS-1?
Is there potential for human disturbance?	Yes	Potential for human disturbance was taken into account during site selection (i.e., Esplanade Bay [Site 103] was specifically cited as having excessive amounts of recreational use relative to most other sites) (Keefer et al. 2008)
Is there grazing by waterfowl or other animals?	No	This apparently was not taken into account, although this does not seem to be an important factor in the Kinbasket Reservoir.
What is the proximity of nearby propagules and their colonization ability?	Yes	The proximity of propagules, specifically live stakes, was discussed in Keefer et al. (2008).
What is the density and species composition of any existing seed bank?	Yes	Existing seed banks were discussed, particularly the abundance of lenticular sedge seeds (Keefer et al. 2007).
Plant Selection		
What are the relevant species characteristics required?	Yes	Relevant species characteristics were chosen as those that permit establishment within the drawdown zone of Kinbasket Reservoir (Keefer et al. 2007).
What suitable species are native or local to the area?	Yes	Plant species diversity of the drawdown zone was investigated in CLBMON-10 (Hawkes et al. 2007), which formed the basis for CLBWORKS-1.
Can a list of target species be produced that is consistent with project goals?	Yes	Species were chosen that had the desirable characteristics for establishment and which were already present in the drawdown zone.
What is the type and source of propagules to be used?	Yes	Seeds and propagules were collected from the drawdown zone of the reservoir or from nearby upland areas (e.g., willows) (Keefer et al. 2008).
Project Management		
Can a set of evaluation guidelines be developed to determine project success?	Partially	Monitoring methodologies are in place, but no benchmarks or long-term goals are presented.
Can the area be adequately accessed for management purposes?	Yes	All access routes were explored in 2007–2008 and were described in Keefer et al. (2008).
What are the proposed planting methods, densities and timing?	Yes	This is well-presented and described in Keefer et al. (2008).
Are there contingency proposals for weed control?	Yes	Measures were put into place to reduce/ eliminate fertilizer treatments once it became clear that weeds (especially Lady's-thumb) were benefitting more than the seedlings.
Is fertilizer to be applied (if so, what type, how much and when)?	Yes	This was discussed in Keefer et al. (2010).
Are there any operational constraints—i.e., vegetation- or root-free zones?	No	This was not investigated during preliminary planning, but it does not appear to be applicable in this instance.
Are there any engineering requirements being placed on the vegetation?	No	N/A
Is the area prone to spray drift of herbicides?	No	N/A
What will the maintenance requirements be during the critical establishment period?	Yes	Post-planting monitoring programs were well-described in Keefer et al. (2008). These monitoring sessions provide opportunity for maintenance of the plantings.
Is there support for post-project monitoring, and has a plan been drawn up?	Yes	Keefer et al. (2008) present a detailed post-planting monitoring protocol. Similar monitoring will occur via CLBMON-9.
Is the project finance viable in the short and long term?	Yes	The proposed program has been operating within budgetary constraints.

6.2.2. Site Selection

Keefer Ecological Services took a variety of environmental and other factors into account during the site selection process in 2007 (Keefer et al. 2007) to help ensure that future revegetation attempts would have the maximum likelihood of success. Factors that were considered included soil properties (physical, chemical), topographical considerations (slope, etc.), exposure to wave action and erosion/deposition, accessibility, and the availability of nearby plant propagules to aid in revegetation/restoration. Each of these factors impacts the ability of the site to support plantings and/or affects the ability of managers and planters to visit the site throughout its planting and establishment phases.

Although most of the factors that were considered during the site verification process were appropriate, the susceptibility of sites to woody debris accumulation does not appear to have been considered, despite the magnitude of effect that excessive woody debris accumulation could have on revegetated polygons. Thus, the failure of some of the planting sites to prosper, especially due to woody debris accumulation, suggests that greater care should have been taken to ensure that only the most suitable sites were chosen. For example, at Windfall Creek in 2011, excessive woody debris accumulation overtop of existing revegetation polygons necessitated mechanical removal of the debris. The damage associated with the woody debris accumulation, compounded by the soil compaction and disturbance associated with the subsequent debris removal, eliminated this site as a revegetation polygon. Surveys in 2011 showed that all vegetation at this site had been removed through this process (Figure 6-1). Consideration of woody debris patterns in Kinbasket Reservoir during site verification would have alerted Keefer Ecological Services to the possibility that disruption to the planting program may occur at the site due to woody debris accumulation.

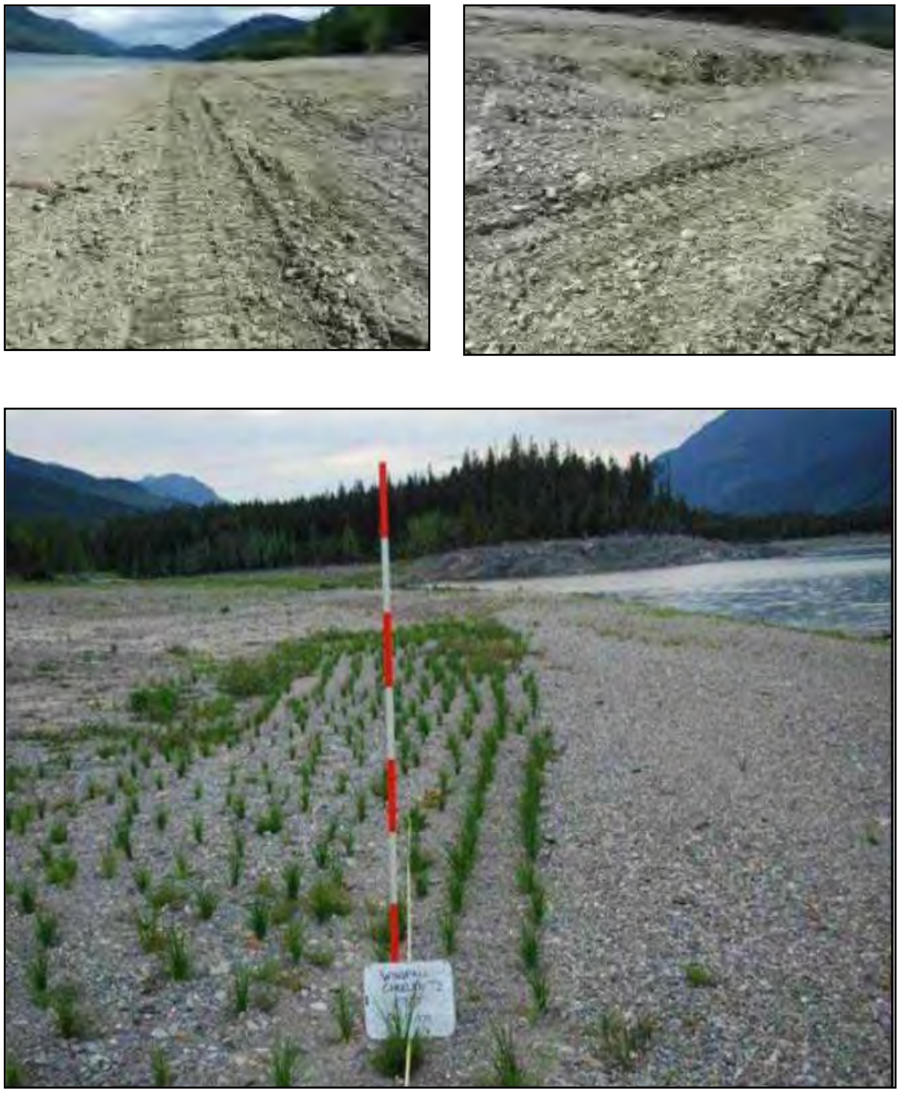


Figure 6-1: **Damage to revegetation polygon due to woody debris accumulation and subsequent removal (upper photos). Note the complete lack of vegetation and heavy soil disturbance related to the mechanical removal of the accumulated woody debris. This same site is shown prior to the disturbance from the woody debris removal (lower photo) (from Keefer et al. 2010).**

6.2.3. Plant Physiology and the Selection of Species

A thorough review of the physiological characteristics of the species that are proposed for use in revegetation efforts is an important component of a successful revegetation program. This allows planters and managers to understand the ecological conditions best suited to supporting the growth of each species based on its physiological requirements, thereby potentially increasing the likelihood of successful establishment. Although the species selected for the revegetation efforts by Keefer Ecological Services in 2007 were based upon species that were currently growing within the drawdown zone of the Kinbasket Reservoir (and which, presumably, had physiological characteristics that allowed them to successfully colonize this harsh environment), the physiological characteristics of those species apparently were not reviewed to ensure that the areas in which they were grown would best support them. The substrate, elevation and moisture regimes of the sites were taken into account, but the physiology of the chosen species was not. Without a proper investigation of the limits of each species' physiological tolerances, it is difficult to gauge whether those species can endure the conditions presented by reservoir operations. The number of potentially confounding factors makes it difficult to determine the causes of success or demise of revegetation efforts across the drawdown zone.

Literature on species-specific plant physiology is scarce, and information on long-term impacts on species' survival due to events such as drought or inundation is even scarcer; however, a number of information sources are available for review and should have been investigated prior to the initiation of the planting program, particularly during the site selection phase. Information gained through a review of species' physiological characteristics, when used in conjunction with field observations of habitats in which the species are growing, can help define the conditions that are the most suitable for each species to prosper.

As an example, the following section provides a summary of some of the physiological and ecological characteristics of the most widely planted species in this revegetation program. It provides an indication of the suitability of each species for revegetation in the drawdown zone of the reservoir and provides guidance for future plantings, highlighting the importance of considering the physiology and ecological amplitude of the plant being used. This is intended to provide a background upon which a more thorough understanding of each species can be developed, which can ultimately better guide revegetation efforts going forward. Although all of the species discussed are considered suitable for planting in the drawdown zone of Kinbasket Reservoir, consideration of this ecological information when selecting microsites for revegetation would likely improve the success of the individual plantings.

6.2.3.1. Water Sedge

Water Sedge (*Carex aquatilis*) naturally forms extensive stands in habitats such as wet meadows and bogs, and along streams and lakeshores, which either maintain a high water table or are poorly drained and retain water in the root zone year round (Wilson et al. 2008). In B.C., the average soil moisture regime for this species is subhydric (Klinkenberg 2011). Subhydric soils are characterized by a water table at or near the surface for most of the year, poor drainage, and very shallow slope gradients (BC MOE 1998). This species has a high anaerobic tolerance but cannot handle the stress of being in standing water throughout the year. The drought resistance of water sedge is low (Tilley et al. 2011) and it is unlikely to perform well under prolonged periods where water is absent from the root zone.

Fine- and medium-textured soils are suitable substrates for water sedge but it is not adapted to coarser substrates (Tilley et al. 2011), presumably due to the efficient drainage of such soils. In a study on subalpine riparian and wetland plant associations in Oregon, *C. aquatilis* was found growing in shallow gradient (≤ 5% slope) valleys, and plot-specific slopes were ≤ 2% (Wells 2006). This likely reflects water sedge's affinity for poorly drained soils.

The ability of a species to provide cover in drawdown areas may also depend on its ability to reproduce and spread vegetatively. Water Sedge is regarded as having a slow seed spread rate, and the seedling vigour is medium (Tilley et al. 2011); however, reproduction is typically asexual, arising from spreading rhizomes (Tilley et al. 2011). Using plug seedlings to establish a population is the recommended procedure for revegetation with water sedge, which is consistent with the revegetation prescriptions that were used in CLBWORKS-1. The use of seeds is less successful because more aggressive exotic grasses can establish more quickly and take up resources (Wilson et al. 2008), and seedling recruitment is naturally infrequent (Tilley et al. 2011).

Once established, a rhizomatous network of connected ramets may provide *C. aquatilis* with a greater capacity to cope with anaerobic stress as resources are spread out and can be allocated accordingly (Steed et al. 2002). Ultimately, a mature plant faced with prolonged inundation will shift its resources to the roots and away from aboveground biomass due to a decrease in the uptake of nutrients. Many plants that experience periodic flooding produce aerenchyma, creating a network of air spaces in the root cortex which allows the plant to aerate internally and avoid injury from the buildup of harmful gases (Visser et al. 2000).

Water Sedge is known to form well-developed aerenchyma (Hauser 2006), which makes it well-adapted to periodic inundations due to reservoir operations when grown under natural conditions. When attempting to establish Water Sedge populations, however, it is recommended that the transplant soil should remain saturated and should not have a standing water level greater than 2.5 cm or 5.0 cm until the plants have approximately 30 cm of aboveground growth (Tilley et al. 2011). If plug seedlings with very little aboveground biomass are inundated prematurely, they may not have the capacity for adequate oxygen uptake to fuel respiration (Visser et al. 2000). Additionally, the reduced leaf gas exchange, evidenced by the decrease in stomatal conductance and net photosynthetic rate, indicates that high water tables may be limiting to transplant seedlings. Overall, this research suggests that the capacity of transplanted Water Sedge plants to cope with changes in the water table is lowered compared to naturally occurring plants, particularly if the seedlings do not have sufficient aboveground biomass to adequately uptake oxygen prior to inundation.

6.2.3.2. Kellogg's (Lenticular) Sedge

Kellogg's Sedge (*Carex lenticularis* var. *lipocarpa*) is found in areas where water levels fluctuate, such as lakeshores, riverside pools and the margins of reservoirs (Wilson et al. 2008). This species has medium anaerobic capacity and low drought tolerance, and is adapted to medium- and coarse-textured soils but not finer substrates (USDA-NRCS 2011). It is a common, naturally-occurring species in the drawdown zone of Kinbasket Reservoir, and its capacity to tolerate fluctuating water levels made it a logical choice for revegetation. Kellogg's sedge is known to establish on disturbed sites (Wilson et al. 2008), which lends further credence to its use for revegetation. Furthermore, once established, this species has the potential to form a dominant cover if the tussocks are densely packed enough to exclude competition and the substrate remains appropriately saturated (Wilson et al. 2008). Field observations of revegetated areas have indicated that the success of individual plantings in the reservoir is highly variable, with some being highly successful in establishing from seedling plugs while others fail completely. This is likely related to the hydrology and substrate at each site as these factors are integral to the success of revegetation.

Kellogg's Sedge is said to have a low seed spread rate, low seedling vigour and slow vegetative spread (USDA-NRCS 2011). A contrasting account claims this species has the ability to produce a large number of seeds that readily sprout on soils exposed along receding water lines (Wilson et al. 2008). This latter reference agrees with field observations around Kinbasket Lake, where seedlings of this species are common on areas of bare substrate that are exposed as the reservoir's water level drops. The fate of these seedlings is not known, but presumably prolonged periods of inundation or sediment deposition results in extremely low survivorship.

Kellogg's Sedge has been less intensively studied than Water Sedge, but it likely shares many adaptations and physiological responses. It should be noted, however, that Kellogg's Sedge is considered to be a facultative wetland species and it has short, ascending rhizomes that form individual large tussocks, whereas water sedge is considered to be an obligate wetland plant and it has long, rapidly spreading rhizomes originating from a genet leading to a series of ramets. Regardless of their differences in growth form, it is expected that Kellogg's sedge undergoes similar responses to that of Water Sedge—translocation of resources from aboveground biomass to the roots, formation of aerenchyma, and a decrease in leaf gas exchange—when it experiences prolonged anoxic or hypoxic conditions. Direct observations and indirect evidence pertaining to other *Carex* species with similar hydrologic requirements seem to add weight to this suggestion (e.g., Visser et al. 2000, Steed et al. 2002, Wilson 2006).

6.2.3.3. Small-fruited Bulrush

Small-fruited Bulrush (*Scirpus microcarpus*) is found naturally in marshes, wet meadows, and ditches (Whittemore and Schuyler 2002) where the soil moisture regime ranges from mesic to hydric (Klinkenberg 2011). The soils on which it occurs typically maintain a water table at or near the surface for most of the year, have poor drainage, and are found on very shallow slope gradients (BC MOE 1998). The species has a high anaerobic tolerance and is often found in standing water up to 2.5 m deep (USDA-NRCS 2011). Small-fruited Bulrush is adapted to fine-, medium- and coarse-textured soils and does not tolerate drought (USDA-NRCS 2011). Unfortunately, very little literature pertaining to the specific physiology of this species exists, and the limited literature available (e.g., Cooke and Azous 1997, Wells 2006, USDA-NRCS 2011) is not necessarily consistent between sources.

Small-fruited Bulrush occurs infrequently within the drawdown zone of Kinbasket Reservoir and only on microsites that are consistent with the species' fairly narrow hydrologic tolerances. Only 10 observations have been recorded during the CLBMON-9 surveys over three field seasons, all of which are from the Valemount Peatland (although it also occurs at low densities in Bush Arm and other areas as well). The natural absence of a species in an area may indicate that the habitat is not suitable for its establishment, or it is unable to compete with other existing vegetation. As a result, this species may not be an ideal choice for revegetation in certain reaches of Kinbasket Reservoir except on microsites that are particularly saturated within the upper elevation bands.

6.2.3.4. Wool-grass

Wool-grass (*Scirpus atrocinctus*) is found naturally in marshes, moist meadows, ditches, and disturbed areas (Whittemore and Schuyler 2002), and it is known to have a high anaerobic tolerance (USDA-NRCS 2011). In B.C., the BEC database indicates that this species tolerates a soil moisture regime ranging from mesic to hydric, with the average being subhydric (Klinkenberg 2011). Subhydric soils maintain a water table at or near the surface for most of the year, experience poor drainage, and are found on very shallow slope gradients (BC MOE 1998). Like Small-fruited Bulrush, Wool-grass is adapted to fine-, medium- and coarse-textured soils, and it does not tolerate drought (USDA-NRCS 2011). Compared to Small-fruited Bulrush, Wool-grass inhabits areas that are, on average, wetter during the early portion of the growing season and have lower water level fluctuations throughout the growing season (Cooke and Azous 1997). It is frequent throughout much of the drawdown zone of Kinbasket Reservoir, particularly in areas of saturated soils (e.g., seepage areas, pond margins, etc.).

Information on the effects of flooding on Wool-grass is limited because the species was recently split from *S. cyperinus*, but studies have used congeners, and the results should be applicable to the target species. However, studies on *S. cyperinus* have shown that, in response to inundation, net photosynthesis decrease over the first several days of inundation but within a week the plants begin to recover (Spencer 1994). After two weeks, individuals nearly recover to pre-inundation net photosynthesis rates. Thus, this species (and, by proxy, *S. atrocinctus*) appears to be very well adapted to the widely fluctuating inundation regimes that occur in the drawdown zone in association with reservoir operations. However, because this species does best on moist microsites, site selection should factor into the decision-making process regarding revegetation.

6.2.3.5. Black Cottonwood

Black cottonwood (*Populus trichocarpa*) is typically found along streams and in other very moist conditions, is well adapted to seasonal water fluctuations, and has a high tolerance for flooding (Polzin 1998). Cottonwoods are adapted to fine- medium- and coarse-textured soils (USDA-NRCS 2011) that maintain a saturated water table (Polzin 1998). Despite this inherent capacity to withstand flooding and periodic inundation, this species has only a moderate tolerance to anaerobic conditions and a low tolerance to both water stress and exposure to drought (USDA-NRCS 2011). It is a common component of upland forested communities adjacent to the drawdown zone of Kinbasket Reservoir, commonly occurring into the upper elevation bands (although these individuals rarely reach maturity). Low drought tolerance is the primary concern in using this species to revegetate areas of the drawdown zone of Kinbasket Lake (Rood et al. 2003).

A study on the physiological response by seedlings of two species, including black cottonwood, to flood conditions identified several changes that occurred over the flooding period: (1) altered nutrient uptake and transport, (2) production of adventitious roots originating from the stem, (3) production of aerenchyma, (4) dieback of roots, (5) production of lenticels, and (6) decreased water xylem potential and root hydraulic conductance (Harrington 1987). Due to the numerous adaptations exhibited by black cottonwood, the species has excellent potential for revegetating sites with saturated or periodically inundated water tables.

Although black cottonwood is subject to drought mortality (Rood et al. 2003), and is only moderately tolerant of anaerobic conditions created by inundation, it appears to be a suitable choice for revegetating upper portions of the drawdown zone with woody vegetation. Its low drought tolerance, however, will limit its applicability to sites with a high water table and/or fine sediments as coarse sediments and a low water table would result in rapid draining and subsequent drought conditions, even adjacent to a large water body such as Kinbasket Reservoir.

6.2.4. Planting Methodology

The planting methodologies used by Keefer Ecological Services generally align with methodologies used in other revegetation programs throughout North America. This includes propagation of plug seedlings, collection and planting of live stakes, and use of fertilizer treatments and hand seeding. Although many of the specific methods used in the planting program appear to align with suitable methodologies used elsewhere, some issues are nonetheless apparent (particularly with the sourcing and planting of willows).

Although efforts were made to source stock locally for use in live stake and seed treatments, uncertainties regarding the identity of some of the sources of live stakes (specifically, willows) may explain some of the difficulties that have occurred in successfully establishing those species in the drawdown zone. For example, Keefer et al. (2008) state that the willow stakes that were collected for planting within the drawdown zone came from a species that ―most closely resembled Scouler's willow (*Salix scouleriana*)". The genus *Salix* is very large and complex, and its numerous species have very different ecological tolerances (Argus 2010). Even within the Bush Arm area, where the stakes were collected and planted, more than a dozen species are expected to occur, each of which has a different ability to persist when planted in the drawdown zone of the reservoir. In fact, Scouler's Willow is probably one of the few species that is more adapted to upland habitats (forest edges, clearings, roadsides) than to wetlands or areas that are subject to periodic inundation, and thus may not be a particularly good choice for the revegetation program.

Furthermore, the collection of the stakes from roadsides and other upland habitats, rather than from existing populations within the drawdown zone, increases the likelihood of collecting stakes from individuals that are more ecologically adapted to upland conditions. Populations within the drawdown zone would presumably have minor ecological adaptations that would allow them to survive under the conditions present within the reservoir basin. According to Abrahams (2006), local transplants should be used where possible, and preferably should be taken from the same water body and water depth range because they will be ecotypically adapted to the conditions prevalent in the area. Thus, the selection of Scouler's willow as a source of live stakes, particularly when the actual identity of the plant is somewhat uncertain and stakes have been collected from upland localities, may explain some of the difficulties that have occurred in establishing willow stakes in the drawdown zone. 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 increase the survivorship of the stakes.

6.2.5. Post-planting Monitoring and Adaptive Management

Post-planting monitoring for CLBWORKS-1 began immediately following the first planting session in spring 2008, and it continued regularly throughout the following years (up to, and including, 2011). This monitoring was designed to track the establishment of the planted or seeded plant communities by monitoring such factors as species composition, vegetation cover, and seedling and live stake survivorship. Monitoring was done by Keefer Ecological Services, as part of the CLBWORKS-1 program, and externally by LGL Limited as part of the CLBMON-9 program. Based on the data collected during the 2009–2011 period, it appears that revegetation efforts within the drawdown zone of Kinbasket Reservoir are struggling to establish and persist. Although Keefer et al. (2010) report that sedge plugs were establishing at a good rate at most sites and were surviving the first inundation cycle with minimal mortality, monitoring from CLBMON-9 has indicated that the mortality rate increases sharply following the first inundation cycle and continues to increase through at least the first two years of establishment (see Results). These trends suggest that successful establishment of extensive natural plant communities within the drawdown zone will not occur without attention to the factors that are contributing to this mortality. Fortunately, however, the post-planting monitoring has allowed for the detection and quantification of mortality rates and will thus provide an opportunity for adaptive management moving forward.

Keefer et al. (2011) report some similar concerns regarding the establishment of vegetation in the drawdown zone, including poor survivorship and potential competition with invasive species (e.g., lady's-thumb [*Polygonum persicaria*]). As a result of these concerns, CLBWORKS-1 has begun to implement some adaptive management techniques to help remedy or mitigate these concerns. For example, when it was determined that fertilizer application was disproportionately benefitting invasive annual species rather than the establishing seedlings in 2009, all fertilizer treatments were halted (Keefer et al. 2011). Similarly, due to extreme difficulties in establishment, planting at low elevations and on fine substrates was halted in order to focus more effort on higher elevation bands or those with coarser substrates, which tended to have greater success rates. Keefer et al. (2010) also found that small-fruited bulrush and bluejoint reedgrass did well only on wet sites at high elevations in the drawdown zone, and the planting program was changed so that these two species were planted only on such sites to increase their chances of establishment. Other examples of adaptive management in the program include the planting of rooted seedlings rather than live stakes (in response to data that show greater survivorship of seedlings), and restricting the planting of cottonwood to the uppermost elevation bands (in response to data that demonstrate greatly increased mortality below the uppermost elevations bands) (Keefer et al. 2010). Thus, by adapting the planting program to incorporate information gained through the monitoring program, the survivorship of future revegetation polygons has potentially increased, and the overall revegetation program will presumably be more successful. See Conclusions and Recommendations for additional opportunities for adaptive management.

7.0 Conclusions and Recommendations

It is evident from the results of the 2011 CLBMON-9 assessment that revegetation efforts in the Kinbasket Reservoir are struggling to succeed. A number of factors likely contribute to the difficulties in plant establishment, some of which may be remedied by changes in protocol, while others (e.g., reservoir operations) may be beyond the scope of this project. Results of field surveys conducted in 2011 showed virtually no statistically significant landscape-level differences between treated and control plots anywhere in the reservoir, which suggests that current 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). For example, mortality rates among revegetated plots were very high: nearly 100 per cent of live stakes, and up to 50 per cent of plug seedlings. Therefore, there has not been a significant landscape-level increase in the areal extent, quality, or productivity of the revegetated polygons.

Despite these challenges, some changes that were incorporated into the revegetation program between 2008 and 2011 appear to have been successful. For example, competition with the exotic weed Lady's-thumb has been reduced through the cessation of fertilizer treatments, which disproportionately benefitted the exotic species over the replanted species. Similarly, switching from live stakes, which have extremely high rates of mortality, to deciduous seedlings, which have much lower mortality rates, appears to have improved the survivorship of woody species. Nonetheless, opportunities for additional improvements and alterations to the project exist, which would further improve the rates of vegetation establishment.

Despite some minor successes, the results of the 2011 revegetation effectiveness study suggest that the current program is not meeting the environmental and social objectives of CLBWORKS-1. Specifically, the program has struggled to meet these objectives, as follows:

i. Maximize vegetation growth in the drawdown zone

Analysis of vegetation cover of treated and control plots in 2011 indicated that no significant increases in cover could be detected among any of the strata tested. In fact, the strongest (though non-significant) trends largely suggested that some treated areas had noticeably lower per cent cover of vegetation than the adjacent control conditions. Examples of this were found in the KS community, at high elevations, and in areas that were hand-seeded, all of which had slightly lower per cent cover after treatment. Only in areas that received both hand-planted stakes and a plug seedling treatment did per cent cover trend upwards. All other strata showed no noticeable change (increase or decrease) in per cent cover.

Similarly, mortality rates, as demonstrated by survivorship data, suggested that most of the treated sites are experiencing rapid and high levels of mortality. After two years, less than 40 per cent of the plug seedlings were still alive. In addition, the overall vigour of these plots decreased substantially over the same time period. Thus, even though nearly 40 per cent of the plug seedlings were still alive, almost all treated

LGL Limited environmental research associates plots had poor to moderate vigour. It is anticipated that this trend will continue.

Based on these results, it is apparent that the CLBWORKS-1 program is not achieving the objective of maximizing vegetation growth within the drawdown zone of Kinbasket Reservoir.

ii. Provide benefits to littoral productivity and wildlife habitat through increased plant species diversity

Although this is a stated objective of CLBWORKS-1, the CLBMON-9 revegetation effectiveness program is not designed to test it. However, this objective is related to plant species diversity, which has not been found to increase (see Objective 3, below). Therefore, it is very unlikely that this objective is being met through CLBWORKS-1.

iii. Increase the species diversity of native plants, particularly those of interest to First Nations

As with per cent cover, none of the strata tested showed a significant increase in either plant species diversity or species richness in treated plots over control plots. Positive trends included slightly higher diversity and richness in areas that had received both hand-planted stakes and a plug seedling treatment, and slightly higher species richness in areas that received only hand-planted stakes, but neither of these trends was statistically significant. Indeed, they are tempered by the slightly lower (though non-significant) species diversity in the LL community after treatment. Thus, it appears that overall the program is not achieving any significant increase in either species diversity or species richness, and as a result, is not meeting this objective.

iv. Improve shoreline stability through targeted planting, where possible

Kinbasket Reservoir is a highly dynamic system, and high levels of both erosion and deposition occur continually throughout the drawdown zone. Although shoreline stability was not specifically tested through the CLBMON-9 revegetation effectiveness monitoring program, there was no evidence during the 2011 field season that the revegetated plots were reducing erosion. Shoreline stability is directly related to an increase in per cent cover of vegetation (and the parallel increase in below-ground biomass). Given that plant establishment is very limited and per cent cover has not increased through revegetation, it can be assumed that few of the revegetation polygons have established enough to reduce shoreline erosion. As a result, it does not appear that CLBWORKS-1 is meeting this objective through the revegetation program.

v. Provide protection for known archaeological sites, where possible

This objective was not specifically tested through CLBMON-9, but as with shoreline stability, the protection of archaeological sites through the establishment of vegetation communities is directly related to the increase in per cent cover and subsequent increase in the soil-binding properties of the below-ground biomass. Because no increases in per cent cover have been detected, it can be assumed that CLBWORKS-1 is not meeting this objective.

Based on this assessment of the status of the CLBWORKS-1 revegetation program, we provide the following recommendations for improving the success of the program in future planting years. These recommendations 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.

1) Modify the scope of work for CLBMON-9 so that the focus is only on effectiveness monitoring.

- The current scope of work for CLBMON-9 overlaps substantially with that of CLBMON-10. 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. Changes in existing vegetation relative to reservoir operations, human-induced disturbance, and wildlife are being addressed in that study. The only aspect of existing vegetation that should be retained from CLBMON-10 is the collection of data in existing vegetation communities during the same implementation years of CLBMON-9 so that direct comparisons between vegetation variables in existing, control and treated areas can be made. We suggest that the following management questions and associated hypotheses be dropped from CLBMON-9:

  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 is 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)?

  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).

The scope of work for CLBMON-9 could also be included in CLBMON-10 such that all aspects of the existing vegetation and revegetated areas are considered on the same schedule. This would lead to financial efficiencies for BC Hydro while retaining the scope of work for both CLBMON-9 and -10.

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 mean that the proposed schedule for CLBMON-9 needs to be modified.

2) **Change the sourcing of willow stakes by moving away from collecting stakes of "Scouler's-type" willows from upland localities and moving towards collecting stakes of Sitka or Pacific willows from within the drawdown zone.**

   - Scouler's willow is predominately a species of upland habitats, and as such, it is not a preferred option for revegetation of drawdown zone habitats. Sitka and Pacific willows grow abundantly in such habitats and should be chosen over Scouler's willow, if possible. Furthermore, any willow stakes that are planted in the drawdown zone should be collected from within the drawdown zone so that they have a higher likelihood of being adapted to the ecological conditions in which they are planted.

3) **Better incorporate wave and wind patterns into the planting program design to eliminate sites that may be subject to excessive erosion, deposition or woody debris accumulation.**

   - 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 understand wave and wind patterns (fetch) in the reservoir so that sites with high exposure can be excluded from revegetation. For example, Hawkes et al. 2010 assessed the prevailing wind patterns in Kinbasket Reservoir and used that information to assess why species richness and diversity increased in certain vegetation communities. The wind data could also be used to identify those areas of the drawdown zone that are prone to woody debris accumulation. 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).

4) **Replant some treatment sites to augment struggling plantings.**

   - Transplantation projects commonly suffer from increased rates of mortality during the first years following planting, a term commonly known as transplant shock (Shumar and Anderson 1987). Populations may not become established and independently reproducing without some periodic augmentation. Such augmentation should be considered for some revegetation sites within Kinbasket Reservoir, although it should be considered only for sites at which the mortality rates are less than 50 per cent over the first three years following planting (this will exclude sites with higher mortality rates which, presumably, indicate sites with the least ideal conditions for seedling establishment). Continued monitoring of the sites following augmentation will determine whether additional augmentation will be necessary in future years.

5) **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 more consistent year-to-year flood events and the cessation of full pool events, would help promote natural revegetation within the drawdown zone. This 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.

     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. For example, Kinbasket Reservoir was operated to full pool in 2007 for the first time in six years. This resulted in the die-off of woody-stemmed plants and other vascular plants in the upper elevations of the drawdown zone (see Hawkes and Muir 2009, Hawkes et al. 2010). In 2008, 2009 and 2010, revegetation treatments, including the planting of woody-stemmed plants and other vascular plants were conducted at elevations between 742 and 753 m ASL. In 2011, Kinbasket Reservoir was operated to full pool. Given the results of the full pool event in 2007, it is likely that all revegetation efforts over the last four years (i.e., 2008 through 2011) will be directly impacted by reservoir operations. The cumulative effects of reservoir operations and poor survivorship could result in complete vegetation failure.

     We know that certain species of plants are able to withstand extraordinary levels of wet and dry stress; however, if Kinbasket Reservoir continues to be operated as it has been since 2007, the revegetation program will likely be a complete failure, and the ability of vegetation to establish and develop in the drawdown zone will be severely hampered. If this is the case, then it is unlikely that the distribution of vegetation in the drawdown zone will increase and the communities that occur there will continue to persist (barring large scale erosion or deposition events, which do occur in the drawdown zone of Kinbasket Reservoir).

6) **Undertake a comprehensive review of the physiological adaptations of the most abundant plant species within the drawdown zone, particularly those that are being used or could be used in the revegetation program, to determine if their physiology is compatible with their use in the revegetation program.**

    - A comprehensive understanding of the physiological adaptations and ecological tolerances of the plant species that have been selected for the revegetation program apparently has not been completed. This may partially explain some of the problems that have occurred with the establishment of vegetation within the drawdown zone, as species may have been planted in areas in which they are ill equipped physiologically to succeed. The ecological conditions within the drawdown zone of any reservoir are extremely challenging for most plant species' survival, and only those species that are able to tolerate or flourish in those conditions should be used. Some background information on the physiology of such species has been presented in this document, but it is recommended that a more exhaustive effort (through research and a comprehensive literature review) be undertaken to ensure that only the species that are best adapted to the conditions within the reservoir are incorporated into the planting regime.

7) **Implement physical works projects within the drawdown zone to make conditions more suitable for the establishment of vegetation communities.**

    - In many areas of the reservoir, local conditions at a site may preclude establishment of vegetation. Physical works projects aimed at enhancing the conditions at a site may allow for revegetation to occur in areas where it would otherwise be difficult, if not impossible, for vegetation to establish. Potential projects may include the retention of water in pools to create permanent wetlands within the drawdown zone (see Hawkes and Fenneman [2010] and Hawkes and Howard [2011] for an example of where this has been applied in other reservoir systems).

8) **Improve the identification of 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 (Keefer Ecological Services) and representatives of BC Hydro.

9) **Improve integration of the CLBWORKS-1 and CLBMON-9 programs so that revegetation efforts under CLBWORKS-1 occur in conjunction with the monitoring activities of CLBMON-9 and to enable effective study and monitoring.**
    - 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.

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9.0 APPENDICES

Appendix A: Vegetation species documented from the plots established in the drawdown zone of Kinbasket Reservoir (739 m–754 m ASL) sampled during 2011 field work

Species Code	Common Name	Scientific Name
ACHIMIL	common yarrow	*Achillea millefolium*
ACHIALP	Siberian yarrow	*Achillea alpina*
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*
ANTEPUL	showy pussytoes	*Antennaria anaphaloides*
ARABGLA	tower mustard	*Turritis glabra*
ARENSER	thyme-leaved sandwort	*Arenaria serpyllifolia*
BETUPAP	paper birch	*Betula papyrifera*
BIDECER	nodding beggarticks	*Bidens cernua*
CALACAN	bluejoint reedgrass	*Calamagrostis canadensis*
CALASTR	slimstem reedgrass	*Calamagrostis stricta*
CALLPAL	wild calla	*Calla 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	Crawe's sedge	*Carex crawei*
CAREFLA	yellow sedge	*Carex flava*
CAREGAR	Garber's sedge	*Carex garberi*
CAREINT	inland sedge	*Carex interior*
CARELAS	slender sedge	*Carex lasiocarpa*
CARELEN	Kellogg's sedge	*Carex lenticularis var. lipocarpa*
CAREPAC	thick-headed sedge	*Carex pachystachya*
CARESAX	russet sedge	*Carex saxatilis*
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*
CIRSVUL	bull thistle	*Cirsium vulgare*
COLLLIN	narrow-leaved collomia	*Collomia linearis*
COMAPAU	marsh cinquefoil	*Comarum palustre*
CORNCAN	bunchberry	*Cornus canadensis*
CORNSTO	red-osier dogwood	*Cornus stolonifera*

Species Code	Common Name	Scientific Name
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*
DICHACU	western witchgrass	*Dichanthelium acuminatum*
DROSANG	great sundew	*Drosera anglica*
DRYADRU	yellow mountain-avens	*Dryas drummondii*
ELEOELL	Slender spike-rush	*Eleocharis elliptica*
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*
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*
ERIGPHI	Philadelphia fleabane	*Erigeron philadelphicus*
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*
GEUMMAC	large-leaved avens	*Geum macrophyllum*
GNAPULI	marsh cudweed	*Gnaphalium uliginosum*
HIERCAE	yellow king devil	*Hieracium caespitosum*
HIERHIR	common sweetgrass	*Hierochloe hirta*
HIERPIL	mouse-ear hawkweed	*Hieracium pilosella*
HORDJUB	foxtail barley	*Hordeum jubatum*
IMPANOL	common touch-me-not	*Impatiens noli-tangere*
JUNCALP	alpine rush	*Juncus alpinoarticulatus*
JUNCBUF	toad rush	*Juncus bufonius*
JUNCENS	dagger-leaf rush	*Juncus ensifolius*
JUNCFIL	thread rush	*Juncus filiformis*
JUNCNOD	tuberous rush	*Juncus nodosus*
LEUCVUL	oxeye daisy	*Leucanthemum vulgare*
LILIPHI	wood lily	*Lilium philadelphicum*
LOBEKAL	Kalm's lobelia	*Lobelia kalmii*
LONIINV	black twinberry	*Lonicera involucrata*
LOTUCOR	birds-foot trefoil	*Lotus corniculatus*
LYCOUNI	northern water horehound	*Lycopus uniflorus*
LYSITHY	tufted loosestrife	*Lysimachia thyrsiflora*

Species Code	Common Name	Scientific Name
MATRDIS	pineapple weed	*Matricaria discoidea*
MEDILUP	black medic	*Medicago lupulina*
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*
MYOSSCO	European forget-me-not	*Myosotis scorpioides*
PACKPAC	rayless alpine butterweed	*Packera pauciflora*
PACKPAP	Canadian butterweed	*Packera paupercula*
PACKPLA	plains butterweed	*Packera plattensis*
PARNPAR	small-flowered grass-of-Parnassus	*Parnassia parviflora*
PERSMAC	lady's-thumb	*Persicaria maculosa*
PHALARU	reed canarygrass	*Phalaris arundinacea*
PLAGSCO	Scouler's popcornflower	*Plagiobothrys scouleri*
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*
POLYAMP	water smartweed	*Persicaria amphibia var. emersa*
POLYAVI	common knotweed	*Polygonum aviculare*
POPUBAL	black cottonwood	*Populus balsamifera ssp. trichocarpa*
POTENOR	Norwegian cinquefoil	*Potentilla norvegica*
PRUNVUL	self-heal	*Prunella vulgaris*
PYROASA	pink wintergreen	*Pyrola asarifolia*
RANUACR	meadow buttercup	*Ranunculus acris*
RANUMAC	Macoun's buttercup	*Ranunculus macounii*
RANUPEN	Pennsylvania buttercup	*Ranunculus pensylvanicus*
RANUSCE	celery-leaved buttercup	*Ranunculus sceleratus*
RHINMIN	yellow rattle	*Rhinanthus minor*
RORIPAL	hispid yellow cress	*Rorippa palustris*
ROSAACI	prickly rose	*Rosa acicularis*
RUBUARC	nagoonberry	*Rubus arcticus*
RUBUIDA	red raspberry	*Rubus idaeus*
RUBUPUB	dwarf red raspberry	*Rubus pubescens*
RUMECRI	curled dock	*Rumex crispus*
SALIBAC	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	whiplash willow	*Salix lucida*
SALIPED	bog willow	*Salix pedicellaris*
SALIPRO	Mackenzie willow	*Salix prolixa*
SALISIT	Sitka willow	*Salix sitchensis*
SCIRATR	wool-grass	*Scirpus atrocinctus*
SCIRMIC	small-flowered bulrush	*Scirpus microcarpus*
SCUTGAL	marsh skullcap	*Scutellaria galericulata*

Species Code	Common Name	Scientific Name
SELASEL	mountain-moss	*Selaginella selaginoides*
SIUMSUA	hemlock water-parsnip	*Sium suave*
SOLICAN	Canada goldenrod	*Solidago lepida*
SPERRUB	red sand-spurry	*Spergularia rubra*
SPIRDOU	hardhack	*Spiraea douglasii*
STELLON	long-leaved starwort	*Stellaria longifolia*
SYMPCIL	Lindley's aster	*Symphyotrichum ciliolatum*
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 arrrow-grass	*Triglochin palustris*
UTRIINT	flat-leaved bladderwort	*Utricularia intermedia*
VERBTHA	great mullein	*Verbascum thapsus*
VEROBEC	American speedwell	*Veronica beccabunga*
VEROPER	purslane speedwell	*Veronica peregrina*
VIOLADU	early blue violet	*Viola adunca*

Appendix 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 C: Locations and variables of plots sampled in 2011

Plot	Elevation (m)	UTM_East	UTM_North	Type[9]	Vegetation Community[10]	Area	Slope (°)	Aspect
506	751.4	354564.1	5847923	E	SH	North	2	
523	752.0	474995.6	5739345.8	E	CO	South	2	SW
560	753.4	361035.4	5841976.2	E	CO	North	4	NW
567	746.3	453330	5736608.8	E	MA	South	3	W
573	748.1	464214.8	5734994.4	E	CH	South	4	SW
601	753.2	353394.6	5849948.2	E	MC	North	1	NW
602	753.1	353396.9	5849912.5	E	MC	North	1	Flat
603	749.7	354392.7	5848387.5	E	SH	North	1	N
604	751.3	354464	5848109.3	E	SH	North	2	NE
605	754.4	353436.1	5850046	E	CO	North	2	NE
606	753.8	354284.4	5847906.5	E	WS	North	2	NE
607	753.0	354410.3	5847850.4	E	WS	North	2	S
608	753.2	354205.1	5848032.5	E	WS	North	2	N
609	749.0	354799.4	5848258.5	E	TP	North	3	E
610	748.5	354598.2	5848394.7	E	WD	North	2	NE
633	753.4	354801	5846742.6	E	KS	North	2	
634	753.6	354777.4	5846624.3	E	KS	North	2	SW
635	753.5	354732.1	5846620	E	KS	North	1	Flat
636	748.6	355805.7	5846185.6	E	SH	North	2	E
637	748.5	355840.2	5846067.7	E	SH	North	3	E
638	747.3	355961.3	5845907.5	E	SH	North	3	NE
640	749.6	354601.2	5848314.7	E	TP	North	2	NE
641	749.8	354667.5	5848213.2	E	TP	North	1	E
642	749.9	354398.3	5848477.4	E	TP	North	1	Flat
643	752.4	353660.3	5849981	E	LL	North	2	W
644	751.6	353745	5849905	E	LL	North	2	SW
645	751.0	353804.8	5849865.6	E	LL	North	4	E
646	749.8	353921.4	5849819.3	E	LL	North	3	SW
647	749.5	353943.9	5849773.3	E	LL	North	3	S
648	749.1	354186.6	5849565	E	LL	North	1	S
649	752.0	358300.9	5845791.1	E	CH	North	3	NW
650	751.9	358041.1	5845938.7	E	CH	North	5	W
651	748.3	358131.8	5845820.1	E	CH	North	4	S
652	747.3	358050.1	5846039.1	E	CH	North	6	NW
653	741.9	358019.5	5845990.5	E	CH	North	6	W
654	743.5	358068.1	5846220.9	E	CH	North	6	W
674	752.8	355672.4	5845967.8	E	CT	North	3	N
675	752.8	355744.1	5845864.9	E	CT	North	4	NE
676	753.6	355808.9	5845755.1	E	CT	North	3	E
701	746.7	453131.2	5735944.8	E	MA	South	1	S
702	744.4	460543.3	5736233.2	E	CT	South	6	SW

[9] Type: E=Existing; C=Control; T=Treatment

[10] 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.

Plot	Elevation (m)	UTM_East	UTM_North	Type[9]	Vegetation Community[10]	Area	Slope (°)	Aspect
703	746.9	464319.6	5734931.3	E	SH	South	5	W
704	748.8	459887.1	5736266.2	E	BR	South	4	S
705	748.6	460221.8	5736272.1	E	CO	South	5	SE
706	747.2	461785.8	5735473.7	E	WB	South	3	SE
708	749.3	454551.3	5736481.6	E	KS	South	4	SW
709	744.9	453404	5736518	E	MA	South	2	SW
710	747.8	453889.8	5736689.9	E	TP	South	3	SW
711	743.9	462465.7	5735430.5	E	LL	South	4	S
712	750.8	455516.6	5733833.8	E	KS	South	4	E
713	744.6	459806.5	5736286.7	E	BR	South	6	S
714	746.6	460243.6	5736256.7	E	BR	South	4	E
715	742.0	460772.7	5736068.2	E	CT	South	4	S
716	744.4	460026.7	5736250.4	E	CO	South	6	S
717	748.3	454982.5	5736517.6	E	KS	South	4	S
718	748.2	460154.6	5736271.5	E	CO	South	5	S
719	751.9	474870	5739329.1	E	SH	South	1	Flat
720	742.1	460850.4	5735946.2	E	TP	South	4	W
721	750.2	452708.2	5735582.7	E	LL	South	1	NW
722	747.2	460436.2	5736298.4	E	CT	South	7	S
723	746.9	453034.6	5735915.6	E	MA	South	4	
724	743.1	451959.1	5734801.7	E	CH	South	4	
725	750.2	460936.6	5736087.2	E	CT	South	6	SW
726	750.7	452708.3	5735233.6	E	KS	South	1	E
727	745.6	460208.8	5736237.6	E	BR	South	5	S
728	743.2	460079	5736258.4	E	CO	South	7	S
729	744.7	455583.1	5733768.3	E	KS	South	4	SE
730	749.0	460952.8	5735303.5	E	MC	South	3	S
731	745.5	464382.4	5734826.6	E	SH	South	6	N
732	752.7	453565.3	5734450.2	E	CO	South	4	
734	744.1	460298.8	5736272.7	E	BR	South	5	SE
735	746.7	455332.4	5735501.9	E	CH	South	5	
736	750.9	472109.1	5736931.1	E	CH	South	3	N
737	743.0	460828.9	5736057.7	E	CT	South	4	SW
738	744.0	455242.8	5733572.8	E	CH	South	2	SE
740	751.1	460783	5736120.3	E	CT	South	6	S
741	747.9	460131.5	5736276.2	E	CO	South	6	S
742	748.5	452545	5735131	E	KS	South	1	E
743	753.4	472298	5736815	E	MC	South	2	N
744	747.2	455587.8	5734745.3	E	SH	South	4	NE
746	748.7	453364.7	5735816.8	E	MA	South	2	NE
748	750.8	455547.6	5733887.1	E	KS	South	4	SE
749	749.2	460926.2	5735282.4	E	MC	South	5	NE
750	742.5	464277.6	5734878.7	E	SH	South	6	NE
751	746.7	461051	5735310.7	E	LL	South	4	NE
752	746.5	460246.1	5736258.3	E	BR	South	4	E
753	747.2	454781.8	5735480.7	E	CH	South	4	
754	752.9	461648	5735739.7	E	CT	South	3	SW
755	747.1	460830.8	5736079	E	CT	South	6	W
757	744.0	455715.6	5733847.7	E	KS	South	3	E

Plot	Elevation (m)	UTM_East	UTM_North	Type[9]	Vegetation Community[10]	Area	Slope (°)	Aspect
758	752.9	472372.1	5736849.7	E	MC	South	2	NW
759	752.3	474831.5	5739426.5	E	SH	South	1	S
760	748.7	461832.4	5735532.7	E	WB	South	3	S
762	741.9	454715.4	5735554.3	E	CH	South	4	
764	749.2	459824	5735753.1	E	CT	South	5	SE
766	744.6	460348.5	5736282.9	E	BR	South	5	S
767	750.9	472497.5	5736931.1	E	CH	South	4	SE
768	748.8	455499.1	5733783	E	KS	South	4	SE
769	746.9	452868.6	5734964.9	E	CH	South	3	S
770	749.0	460010.5	5735943.3	E	CT	South	5	E
771	750.6	454644.6	5736519.4	E	KS	South	2	S
772	752.8	460901.3	5735345.8	E	MC	South	5	SE
773	742.8	464295.9	5734856.5	E	SH	South	6	NE
774	741.5	460820.8	5736010.7	E	TP	South	3	W
775	742.4	462602.6	5735458.5	E	LL	South	5	S
776	750.3	461731.4	5735587.4	E	WB	South	3	SW
777	753.8	474667.3	5740091.6	E	WS	South	1	E
778	745.7	473873.9	5737751	E	SH	South	2	W
779	748.6	461741.5	5735521.8	E	WB	South	4	SE
780	753.2	474610.5	5740073.4	E	WS	South	3	S
781	742.4	464256.4	5734890.1	E	SH	South	5	
782	747.9	454157.3	5736572.4	E	TP	South	3	SW
783	754.4	474823.9	5740185.6	E	WS	South	1	W
784	751.2	474685.3	5739158.7	E	SH	South	3	SW
785	743.2	459666.5	5736332.2	E	BR	South	4	W
786	741.6	460807.5	5736037.5	E	TP	South	4	W
787	742.8	462167.8	5735353.8	E	LL	South	4	S
788	748.7	460984.3	5735290.4	E	MC	South	5	S
789	747.5	474150.7	5738222.6	E	TP	South	2	W
790	750.7	461635.5	5735599.1	E	WB	South	3	SW
791	746.8	462154.7	5735411.1	E	LL	South	4	SW
796	750.5	461601.3	5735592.1	E	WB	South	5	NE
97	741.7	454220.9	5735775.6	E	MA	South	1	Flat
98	743.6	455162.9	5733633.1	E	CH	South	1	NW
618	750.8	353709.8	5849598.6	C	LL	North	2	SW
627	750.3	353832.4	5849651.5	C	(LL)	North	2	E
628	750.4	353824.3	5849656.1	C	(LL)	North	2	SE
632	749.5	354138.9	5848918	C	SH	North	4	E
661	750.2	373616.7	5827838.9	C	(CO)	North	4	SW
663	749.6	373547.3	5827996.5	C	CO	North	2	
665	749.8	373536.5	5827985.1	C	CO	North	2	NW
668	753.1	361540.8	5841061.8	C	BR	North	5	S
669	753.0	361317.7	5841203.7	C	BR	North	4	S
cont 10	751.1	361177	5841400.9	C	KS	North	3	S
cont 11	752.0	361223	5841294.3	C	KS	North	4	SW
cont 12	752.2	361227.1	5841365.9	C	KS	North	4	W
cont 13	745.2	360930.1	5842205	C	KS	North	4	W
cont 14	750.6	361038.5	5842136.2	C	CH	North	4	W
cont 15	754.5	361094.4	5842094.6	C	CO	North	4	W

Plot	Elevation (m)	UTM_East	UTM_North	Type[9]	Vegetation Community[10]	Area	Slope (°)	Aspect
cont 17	747.2	360969.2	5841607	C	KS	North	4	SW
Cont 1	748.9	361015.8	5841670.5	C	KS	North	4	NW
cont 2	747.2	360970.4	5841814.5	C	KS	North	1	W
cont 3	747.2	360971	5841861.1	C	KS	North	2	W
cont 4	747.1	360955.4	5841949.4	C	KS	North	4	W
cont 5	742.0	360879.4	5842017.1	C	(KS)	North	4	NW
cont 6	740.3	360851.5	5842081.2	C	(KS)	North	4	W
cont 7	749.7	361188.3	5841303.6	C	KS	North	4	W
cont 8	750.3	361198.5	5841278.8	C	KS	North	4	W
cont 9	749.8	361188.9	5841355	C	KS	North	4	SW
wind-c2	746.9	381817.1	5810588.4	C	CO	North	6	NE
wind-c3	743.2	381823.1	5810632.6	C	CO	North	3	SE
561	753.6	361078.6	5841898.5	T	CO	North	4	W
562	749.6	361008.3	5841799.7	T	KS	North	4	NW
565	749.9	361154.6	5841380.6	T	KS	North	3	W
566	746.8	361040.3	5841458.5	T	KS	North	4	SW
611	744.5	360928	5842071.4	T	(KS)	North	4	W
612	743.2	360900.4	5841901.1	T	(KS)	North	5	W
613	751.2	361030.2	5841636	T	KS	North	4	
617	751.3	353607.4	5849593.5	T	LL	North	2	SE
619	750.8	353649.8	5849514.4	T	KS	North	2	E
620	750.7	353751.5	5849506.4	T	LL	North	1	S
621	750.5	353798.5	5849532.5	T	LL	North	3	SE
622	750.2	353867.4	5849523.3	T	LL	North	3	E
623	749.7	353933.3	5849462.9	T	LL	North	1	SW
624	749.8	353929.7	5849370.8	T	LL	North	2	NE
625	749.7	353932.8	5849588.9	T	LL	North	1	E
626	750.2	353882	5849638.8	T	LL	North	1	Flat
629	750.9	353749.1	5849619.7	T	LL	North	2	E
630	749.1	354265.2	5848877.2	T	TP	North	3	E
631	748.2	354212.5	5849031.3	T	TP	North	2	NE
660	751.7	373647.5	5827835.4	T	CO	North	4	SW
662	749.5	373523.6	5827991.5	T	CO	North	3	
664	748.3	373516.1	5828052.6	T	CO	North	3	NW
666	748.7	373512.2	5828028.7	T	CO	North	2	N
667	752.4	373634.1	5827943.3	T	CO	North	3	NW
671	742.2	360882.2	5842068.6	T	(KS)	North	3	W
672	742.5	360863.2	5842127.2	T	(KS)	North	4	SW
673	741.3	360859.5	5842172.1	T	(KS)	North	4	NW
windt2	748.0	381830.1	5810565.5	T	KS	North	5	NE
windt3	743.6	381803	5810642.7	T	LL	North	4	S

Appendix D: Results of analyses of soil samples collected in 2009

Plot	Control/Treatment	Test	Result	Note
10C	C	Organic matter, walkley-black	57.5	% dry
10C	C	Phosphorus, Extractable	0.77	mg/L soil dry
10C	C	Magnesium, Extractable	190	mg/L soil dry
10C	C	Potassium, Extractable	21	mg/L soil dry
10C	C	pH	7.0	
10C	C	Buffer pH	Not analyzed	
10C	C	Nitrogen	1.48	% dry
10T	T	Organic matter, walkley-black	71.3	% dry
10T	T	Phosphorus, Extractable	0.51	mg/L soil dry
10T	T	Magnesium, Extractable	190	mg/L soil dry
10T	T	Potassium, Extractable	25	mg/L soil dry
10T	T	pH	5.7	
10T	T	Buffer pH	6.3	
10T	T	Nitrogen	2.37	% dry
11C	C	Phosphorus, Extractable	<0.85	mg/L soil dry
11C	C	Magnesium, Extractable	32	mg/L soil dry
11C	C	Potassium, Extractable	14	mg/L soil dry
11C	C	pH	6.7	
11C	C	Buffer pH	Not analyzed	
12C	C	Phosphorus, Extractable	<0.85	mg/L soil dry
12C	C	Magnesium, Extractable	37	mg/L soil dry
12C	C	Potassium, Extractable	17	mg/L soil dry
12C	C	pH	6.5	
12C	C	Buffer pH	Not analyzed	
12T	T	Phosphorus, Extractable	<0.85	mg/L soil dry
12T	T	Magnesium, Extractable	35	mg/L soil dry
12T	T	Potassium, Extractable	17	mg/L soil dry
12T	T	pH	6.9	
12T	T	Buffer pH	Not analyzed	
13C	C	Phosphorus, Extractable	19	mg/L soil dry
13C	C	Magnesium, Extractable	27	mg/L soil dry
13C	C	Potassium, Extractable	28	mg/L soil dry
13C	C	pH	5.3	
13C	C	Buffer pH	6.6	
13T	T	Phosphorus, Extractable	4.0	mg/L soil dry
13T	T	Magnesium, Extractable	40	mg/L soil dry
13T	T	Potassium, Extractable	22	mg/L soil dry
13T	T	pH	6.8	
13T	T	Buffer pH	Not analyzed	
14T	T	Phosphorus, Extractable	17	mg/L soil dry
14T	T	Magnesium, Extractable	42	mg/L soil dry
14T	T	Potassium, Extractable	39	mg/L soil dry
14T	T	pH	6.1	
14T	T	Buffer pH	Not analyzed	
15C	C	Organic matter, walkley-black	4.3	% dry
15C	C	Phosphorus, Extractable	7.7	mg/L soil dry
15C	C	Magnesium, Extractable	98	mg/L soil dry

15C	C	Potassium, Extractable	36	mg/L soil dry
15C	C	pH	6.0	
15C	C	Buffer pH	6.5	
15C	C	Nitrogen	0.11	% dry
15T	T	Organic matter, walkley-black	3.7	% dry
15T	T	Phosphorus, Extractable	4.7	mg/L soil dry
15T	T	Magnesium, Extractable	80	mg/L soil dry
15T	T	Potassium, Extractable	28	mg/L soil dry
15T	T	pH	5.7	
15T	T	Buffer pH	6.3	
15T	T	Nitrogen	0.11	% dry
16C	C	Organic matter, walkley-black	0.1	% dry
16C	C	Phosphorus, Extractable	3.4	mg/L soil dry
16C	C	Magnesium, Extractable	90	mg/L soil dry
16C	C	Potassium, Extractable	56	mg/L soil dry
16C	C	pH	8.4	
16C	C	Buffer pH	Not analyzed	
16C	C	Nitrogen	<0.05	% dry
16T	T	Organic matter, walkley-black	0.1	% dry
16T	T	Phosphorus, Extractable	1.6	mg/L soil dry
16T	T	Magnesium, Extractable	58	mg/L soil dry
16T	T	Potassium, Extractable	34	mg/L soil dry
16T	T	pH	8.5	
16T	T	Buffer pH	Not analyzed	
16T	T	Nitrogen	<0.05	% dry
19C	C	Phosphorus, Extractable	2.7	mg/L soil dry
19C	C	Magnesium, Extractable	33	mg/L soil dry
19C	C	Potassium, Extractable	22	mg/L soil dry
19C	C	pH	5.3	
19C	C	Buffer pH	7.1	
19T	T	Phosphorus, Extractable	<0.85	mg/L soil dry
19T	T	Magnesium, Extractable	37	mg/L soil dry
19T	T	Potassium, Extractable	14	mg/L soil dry
19T	T	pH	5.6	
19T	T	Buffer pH	7.3	
1C	C	Organic matter, walkley-black	39.2	% dry
1C	C	Phosphorus, Extractable	7.4	mg/L soil dry
1C	C	Magnesium, Extractable	670	mg/L soil dry
1C	C	Potassium, Extractable	36	mg/L soil dry
1C	C	pH	6.3	
1C	C	Buffer pH	Not analyzed	
1C	C	Nitrogen	2.74	% dry
1T	T	Organic matter, walkley-black	44.8	% dry
1T	T	Phosphorus, Extractable	8.5	mg/L soil dry
1T	T	Magnesium, Extractable	680	mg/L soil dry
1T	T	Potassium, Extractable	25	mg/L soil dry
1T	T	pH	6.5	
1T	T	Buffer pH	Not analyzed	
1T	T	Nitrogen	2.45	% dry
21C	C	Phosphorus, Extractable	<0.85	mg/L soil dry

21C	C	Magnesium, Extractable	90	mg/L soil dry
21C	C	Potassium, Extractable	11	mg/L soil dry
21C	C	pH	8.1	
21C	C	Buffer pH	Not analyzed	
21T	T	Phosphorus, Extractable	<0.85	mg/L soil dry
21T	T	Magnesium, Extractable	100	mg/L soil dry
21T	T	Potassium, Extractable	16	mg/L soil dry
21T	T	pH	8.1	
21T	T	Buffer pH	Not analyzed	
22T	T	Phosphorus, Extractable	4.9	mg/L soil dry
22T	T	Magnesium, Extractable	210	mg/L soil dry
22T	T	Potassium, Extractable	22	mg/L soil dry
22T	T	pH	7.7	
22T	T	Buffer pH	Not analyzed	
23C	C	Organic matter, walkley-black	1.4	% dry
23C	C	Phosphorus, Extractable	2.1	mg/L soil dry
23C	C	Magnesium, Extractable	140	mg/L soil dry
23C	C	Potassium, Extractable	12	mg/L soil dry
23C	C	pH	8.2	
23C	C	Buffer pH	Not analyzed	
23C	C	Nitrogen	0.06	% dry
23T	T	Organic matter, walkley-black	2.3	% dry
23T	T	Phosphorus, Extractable	2.5	mg/L soil dry
23T	T	Magnesium, Extractable	140	mg/L soil dry
23T	T	Potassium, Extractable	12	mg/L soil dry
23T	T	pH	8.2	
23T	T	Buffer pH	Not analyzed	
23T	T	Nitrogen	0.07	% dry
24T	T	Organic matter, walkley-black	1.0	% dry
24T	T	Phosphorus, Extractable	9.8	mg/L soil dry
24T	T	Magnesium, Extractable	110	mg/L soil dry
24T	T	Potassium, Extractable	61	mg/L soil dry
24T	T	pH	6.1	
24T	T	Buffer pH	Not analyzed	
24T	T	Nitrogen	0.05	% dry
31C	C	Organic matter, walkley-black	40.0	% dry
31C	C	Phosphorus, Extractable	7.2	mg/L soil dry
31C	C	Magnesium, Extractable	670	mg/L soil dry
31C	C	Potassium, Extractable	34	mg/L soil dry
31C	C	pH	6.1	
31C	C	Buffer pH	Not analyzed	
31C	C	Nitrogen	3.10	% dry
31T	T	Organic matter, walkley-black	39.6	% dry
31T	T	Phosphorus, Extractable	13	mg/L soil dry
31T	T	Magnesium, Extractable	780	mg/L soil dry
31T	T	Potassium, Extractable	38	mg/L soil dry
31T	T	pH	6.9	
31T	T	Buffer pH	Not analyzed	
31T	T	Nitrogen	3.13	% dry
32C	C	Organic matter, walkley-black	49.0	% dry

32C	C	Phosphorus, Extractable	5.5	mg/L soil dry
32C	C	Magnesium, Extractable	500	mg/L soil dry
32C	C	Potassium, Extractable	20	mg/L soil dry
32C	C	pH	6.9	
32C	C	Buffer pH	Not analyzed	
32C	C	Nitrogen	1.47	% dry
32T	T	Organic matter, walkley-black	40.4	% dry
32T	T	Phosphorus, Extractable	7.9	mg/L soil dry
32T	T	Magnesium, Extractable	640	mg/L soil dry
32T	T	Potassium, Extractable	38	mg/L soil dry
32T	T	pH	6.8	
32T	T	Buffer pH	Not analyzed	
32T	T	Nitrogen	2.33	% dry
3C	C	Organic matter, walkley-black	3.0	% dry
3C	C	Phosphorus, Extractable	6.6	mg/L soil dry
3C	C	Magnesium, Extractable	180	mg/L soil dry
3C	C	Potassium, Extractable	22	mg/L soil dry
3C	C	pH	8.2	
3C	C	Buffer pH	Not analyzed	
3C	C	Nitrogen	0.11	% dry
3T	T	Organic matter, walkley-black	5.1	% dry
3T	T	Phosphorus, Extractable	3.9	mg/L soil dry
3T	T	Magnesium, Extractable	250	mg/L soil dry
3T	T	Potassium, Extractable	27	mg/L soil dry
3T	T	pH	8.1	
3T	T	Buffer pH	Not analyzed	
3T	T	Nitrogen	0.16	% dry
5C	C	Phosphorus, Extractable	11	mg/L soil dry
5C	C	Magnesium, Extractable	330	mg/L soil dry
5C	C	Potassium, Extractable	49	mg/L soil dry
5C	C	pH	7.6	
5C	C	Buffer pH	Not analyzed	
5T	T	Phosphorus, Extractable	6.2	mg/L soil dry
5T	T	Magnesium, Extractable	97	mg/L soil dry
5T	T	Potassium, Extractable	19	mg/L soil dry
5T	T	pH	8.0	
5T	T	Buffer pH	Not analyzed	
6T	T	Organic matter, walkley-black	2.5	% dry
6T	T	Phosphorus, Extractable	10	mg/L soil dry
6T	T	Magnesium, Extractable	84	mg/L soil dry
6T	T	Potassium, Extractable	46	mg/L soil dry
6T	T	pH	5.6	
6T	T	Buffer pH	6.7	
6T	T	Nitrogen	0.07	% dry
7C	C	Organic matter, walkley-black	3.2	% dry
7C	C	Phosphorus, Extractable	10	mg/L soil dry
7C	C	Magnesium, Extractable	42	mg/L soil dry
7C	C	Potassium, Extractable	45	mg/L soil dry
7C	C	pH	4.8	
7C	C	Buffer pH	6.5	

7C	C	Nitrogen	0.10	% dry
8C	C	Organic matter, walkley-black	0.3	% dry
8C	C	Phosphorus, Extractable	5.1	mg/L soil dry
8C	C	Magnesium, Extractable	30	mg/L soil dry
8C	C	Potassium, Extractable	42	mg/L soil dry
8C	C	pH	7.3	
8C	C	Buffer pH	Not analyzed	
8C	C	Nitrogen	<0.05	% dry
8T	T	Organic matter, walkley-black	0.1	% dry
8T	T	Phosphorus, Extractable	5.7	mg/L soil dry
8T	T	Magnesium, Extractable	24	mg/L soil dry
8T	T	Potassium, Extractable	36	mg/L soil dry
8T	T	pH	7.6	
8T	T	Buffer pH	Not analyzed	
8T	T	Nitrogen	<0.05	% dry
9C	C	Phosphorus, Extractable	2.6	mg/L soil dry
9C	C	Magnesium, Extractable	44	mg/L soil dry
9C	C	Potassium, Extractable	38	mg/L soil dry
9C	C	pH	4.6	
9C	C	Buffer pH	6.9	
9T	T	Phosphorus, Extractable	2.3	mg/L soil dry
9T	T	Magnesium, Extractable	32	mg/L soil dry
9T	T	Potassium, Extractable	32	mg/L soil dry
9T	T	pH	4.1	
9T	T	Buffer pH	6.9	

(*) Grain size thresholds (mkm) defined by the percentage of soil (by weight) retained on the sieve with this size mesh

Appendix E: Results of the analyses of biomass samples

Plot	Control/Treatment	Test	Result	Note
10C	C	Total Nitrogen	2.01	% dry
10C	C	Phosphorus	0.150	% dry
10C	C	Potassium	2.21	% dry
10C	C	Magnesium	0.19	% dry
10C	C	Calcium	1.56	% dry
10C	C	Total Carbon	43.80	% dry
10T	T	Total Carbon	39.2	% dry
10T	T	Inorganic Carbon	0.425	% dry
10T	T	Organic Carbon	38.8	% dry
10T	T	Total Nitrogen	2.00	% dry
10T	T	Phosphorus	0.168	% dry
10T	T	Potassium	2.72	% dry
10T	T	Magnesium	0.24	% dry
10T	T	Calcium	1.54	% dry
11C	C	Total Carbon	44.6	% dry
11C	C	Inorganic Carbon	0.128	% dry
11C	C	Organic Carbon	44.5	% dry
11C	C	Total Nitrogen	1.00	% dry
11C	C	Phosphorus	0.060	% dry
11C	C	Potassium	0.96	% dry
11C	C	Magnesium	0.06	% dry
11C	C	Calcium	0.28	% dry
12C	C	Total Carbon	42.4	% dry
12C	C	Inorganic Carbon	0.116	% dry
12C	C	Organic Carbon	42.3	% dry
12C	C	Total Nitrogen	1.07	% dry
12C	C	Phosphorus	0.112	% dry
12C	C	Potassium	1.56	% dry
12C	C	Magnesium	0.10	% dry
12C	C	Calcium	0.60	% dry
13C	C	Total Carbon	40.9	% dry
13C	C	Inorganic Carbon	0.419	% dry
13C	C	Organic Carbon	40.5	% dry
13C	C	Total Nitrogen	1.43	% dry
13C	C	Phosphorus	0.272	% dry
13C	C	Potassium	2.14	% dry
13C	C	Magnesium	0.28	% dry
13C	C	Calcium	1.01	% dry
13T	T	Nitrogen	2.13	% dry
14T	T	Total Carbon	43.2	% dry
14T	T	Inorganic Carbon	0.11	% dry
14T	T	Organic Carbon	43.1	% dry
14T	T	Total Nitrogen	0.77	% dry
14T	T	Phosphorus	0.108	% dry
14T	T	Potassium	0.99	% dry
14T	T	Magnesium	0.07	% dry
14T	T	Calcium	0.19	% dry

15C	C	Total Nitrogen	1.79	% dry
15C	C	Phosphorus	0.304	% dry
15C	C	Potassium	1.66	% dry
15C	C	Magnesium	0.16	% dry
15C	C	Calcium	0.46	% dry
15C	C	Total Carbon	28.10	% dry
15T	T	Total Carbon	18.8	% dry
15T	T	Inorganic Carbon	0.371	% dry
15T	T	Organic Carbon	18.4	% dry
15T	T	Total Nitrogen	1.80	% dry
15T	T	Phosphorus	0.087	% dry
15T	T	Potassium	1.10	% dry
15T	T	Magnesium	0.33	% dry
15T	T	Calcium	1.05	% dry
16C	C	Total Carbon	36.5	% dry
16C	C	Inorganic Carbon	0.271	% dry
16C	C	Organic Carbon	36.2	% dry
16C	C	Total Nitrogen	1.54	% dry
16C	C	Phosphorus	0.25	% dry
16C	C	Potassium	2.91	% dry
16C	C	Magnesium	0.25	% dry
16C	C	Calcium	1.82	% dry
16T	T	Total Carbon	34.9	% dry
16T	T	Inorganic Carbon	0.175	% dry
16T	T	Organic Carbon	34.7	% dry
16T	T	Total Nitrogen	1.68	% dry
16T	T	Phosphorus	0.206	% dry
16T	T	Potassium	3.15	% dry
16T	T	Magnesium	0.30	% dry
16T	T	Calcium	1.90	% dry
19C	C	Total Carbon	42.5	% dry
19C	C	Inorganic Carbon	0.148	% dry
19C	C	Organic Carbon	42.4	% dry
19C	C	Total Nitrogen	2.09	% dry
19C	C	Phosphorus	0.171	% dry
19C	C	Potassium	1.70	% dry
19C	C	Magnesium	0.10	% dry
19C	C	Calcium	0.61	% dry
19T	T	Total Carbon	44.7	% dry
19T	T	Nitrogen	1.08	% dry
1C	C	Total Carbon	36.7	% dry
1C	C	Inorganic Carbon	0.318	% dry
1C	C	Organic Carbon	36.4	% dry
1C	C	Total Nitrogen	3.20	% dry
1C	C	Phosphorus	0.157	% dry
1C	C	Potassium	1.05	% dry
1C	C	Magnesium	0.35	% dry
1C	C	Calcium	1.61	% dry
1T	T	Total Carbon	38.3	% dry
1T	T	Inorganic Carbon	0.222	% dry

1T	T	Organic Carbon	38.1	% dry
1T	T	Total Nitrogen	3.41	% dry
1T	T	Phosphorus	0.175	% dry
1T	T	Potassium	1.20	% dry
1T	T	Magnesium	0.51	% dry
1T	T	Calcium	1.44	% dry
21C	C	Total Nitrogen	1.90	% dry
21C	C	Phosphorus	0.122	% dry
21C	C	Potassium	1.58	% dry
21C	C	Magnesium	0.20	% dry
21C	C	Calcium	0.54	% dry
21C	C	Total Carbon	43.8	% dry
21T	T	Total Nitrogen	2.20	% dry
21T	T	Phosphorus	0.160	% dry
21T	T	Potassium	1.59	% dry
21T	T	Magnesium	0.37	% dry
21T	T	Calcium	1.16	% dry
21T	T	Total Carbon	41	% dry
21T	T	Inorganic Carbon	0.645	% dry
21T	T	Organic Carbon	40.4	% dry
21T	T	Total Nitrogen	0.87	% dry
21T	T	Phosphorus	0.073	% dry
21T	T	Potassium	1.04	% dry
21T	T	Magnesium	0.50	% dry
21T	T	Calcium	2.10	% dry
22C	C	Total Carbon	39.4	% dry
22C	C	Inorganic Carbon	0.188	% dry
22C	C	Organic Carbon	39.2	% dry
22C	C	Total Nitrogen	1.77	% dry
22C	C	Phosphorus	0.093	% dry
22C	C	Potassium	2.32	% dry
22C	C	Magnesium	0.27	% dry
22C	C	Calcium	1.32	% dry
22T	T	Total Carbon	43.6	% dry
22T	T	Inorganic Carbon	0.296	% dry
22T	T	Organic Carbon	43.3	% dry
22T	T	Total Nitrogen	1.62	% dry
22T	T	Phosphorus	0.059	% dry
22T	T	Potassium	0.93	% dry
22T	T	Magnesium	0.21	% dry
22T	T	Calcium	1.07	% dry
23C	C	Total Carbon	42.70	% dry
23C	C	Nitrogen	1.67	% dry
23T	T	Total Carbon	39.5	% dry
23T	T	Inorganic Carbon	0.638	% dry
23T	T	Organic Carbon	38.9	% dry
23T	T	Total Nitrogen	1.87	% dry
23T	T	Phosphorus	0.097	% dry
23T	T	Potassium	0.70	% dry
23T	T	Magnesium	1.03	% dry

23T	T	Calcium	2.42	% dry
24T	T	Total Carbon	25.8	% dry
24T	T	Inorganic Carbon	0.408	% dry
24T	T	Organic Carbon	25.4	% dry
24T	T	Total Nitrogen	2.70	% dry
24T	T	Phosphorus	0.35	% dry
24T	T	Potassium	2.54	% dry
24T	T	Magnesium	0.56	% dry
24T	T	Calcium	1.37	% dry
31C	C	Total Carbon	42.00	% dry
31C	C	Nitrogen	3.14	% dry
32C	C	Total Carbon	43.8	% dry
32C	C	Inorganic Carbon	0.171	% dry
32C	C	Organic Carbon	43.6	% dry
32C	C	Total Nitrogen	2.04	% dry
32C	C	Phosphorus	0.135	% dry
32C	C	Potassium	1.11	% dry
32C	C	Magnesium	0.22	% dry
32C	C	Calcium	0.78	% dry
32T	T	Total Carbon	41.0	% dry
32T	T	Inorganic Carbon	0.528	% dry
32T	T	Organic Carbon	40.5	% dry
32T	T	Total Nitrogen	2.63	% dry
32T	T	Phosphorus	0.134	% dry
32T	T	Potassium	1.31	% dry
32T	T	Magnesium	0.58	% dry
32T	T	Calcium	2.36	% dry
3T	T	Total Nitrogen	1.71	% dry
3T	T	Phosphorus	0.095	% dry
3T	T	Potassium	1.03	% dry
3T	T	Magnesium	0.82	% dry
3T	T	Calcium	2.40	% dry
3T	T	Total Carbon	38.70	% dry
5C	C	Total Carbon	42.2	% dry
5C	C	Inorganic Carbon	0.443	% dry
5C	C	Organic Carbon	41.8	% dry
5C	C	Total Nitrogen	1.22	% dry
5C	C	Phosphorus	0.135	% dry
5C	C	Potassium	1.81	% dry
5C	C	Magnesium	0.35	% dry
5C	C	Calcium	2.15	% dry
5T	T	Total Carbon	42.9	% dry
5T	T	Inorganic Carbon	0.736	% dry
5T	T	Organic Carbon	42.2	% dry
5T	T	Total Nitrogen	2.09	% dry
5T	T	Phosphorus	0.145	% dry
5T	T	Potassium	0.74	% dry
5T	T	Magnesium	0.47	% dry
5T	T	Calcium	2.50	% dry
6T	T	Total Carbon	37.6	% dry

6T	T	Inorganic Carbon	0.266	% dry
6T	T	Organic Carbon	37.3	% dry
6T	T	Total Nitrogen	1.00	% dry
6T	T	Phosphorus	0.367	% dry
6T	T	Potassium	1.50	% dry
6T	T	Magnesium	0.36	% dry
6T	T	Calcium	1.07	% dry
7C	C	Total Carbon	37.5	% dry
7C	C	Inorganic Carbon	0.292	% dry
7C	C	Organic Carbon	37.2	% dry
7C	C	Total Nitrogen	1.04	% dry
7C	C	Phosphorus	0.202	% dry
7C	C	Potassium	1.35	% dry
7C	C	Magnesium	0.29	% dry
7C	C	Calcium	0.92	% dry
8C	C	Total Carbon	35.3	% dry
8C	C	Inorganic Carbon	0.372	% dry
8C	C	Organic Carbon	34.9	% dry
8C	C	Total Nitrogen	1.64	% dry
8C	C	Phosphorus	0.151	% dry
8C	C	Potassium	2.68	% dry
8C	C	Magnesium	0.23	% dry
8C	C	Calcium	2.14	% dry
8T	T	Nitrogen	2.25	% dry

Appendix F: Results of survivorship and vigour analysis of treatment plots

Plot	Treatment	Year Planted	Frame Number	Live Plants	Dead Plants	Total Plants	Survivorship	Vigour
710[a]	PS	2009	1	37	0	37	100	moderate
710[a]	PS	2009	2	38	1	39	97	moderate
710[a]	PS	2009	3	53	0	53	100	moderate
2011.1T	PS	2010	1	37	7	44	84	good
2011.1T	PS	2010	2	61	12	73	84	good
2011.3T	PS	2010	1	15	0	15	100	good
2011.3T	PS	2010	2	18	0	18	100	good
2011.3T	PS	2010	3	31	0	31	100	good
2011.5T	PS	2010	1	16	2	18	89	good
2011.5T	PS	2010	2	13	0	13	100	good
2011.8T	PS	2009	1	3	21	24	13	moderate
2011.8T	PS	2009	2	8	0	8	100	moderate
2011.9T	PS	2009	1	0	0	0	0	poor
2011.9T	PS	2009	2	0	0	0	0	poor
2011.10T	HS	2009	1	0	22	22	0	poor
2011.10T	HS	2009	2	18	16	34	53	moderate
2011.10T	HS	2009	3	1	5	6	17	poor
2011.13T	PS	2009	1	13	8	21	62	poor
2011.13T	PS	2009	2	17	13	30	57	poor
2011.13T	PS	2009	3	13	0	13	100	good
2011.14T	HPL/PS	2009	1	0	3	3	0	poor
2011.14T	HPL/PS	2009	2	0	6	6	0	poor
2011.16T	PS	2009	1	13	4	17	76	moderate
2011.16T	PS	2009	2	4	16	20	20	poor
2011.18T	PS	2009	1	0	0	0	0	poor
2011.18T	PS	2009	2	0	0	0	0	poor
2011.20T	HPL/PS	2009	1	0	5	5	0	poor
2011.20T	HPL/PS	2009	2	0	2	2	0	poor
2011.21T	HPL	2008	1	0	2	2	0	poor
2011.21T	HPL	2008	2	0	2	2	0	poor
2011.22T	HPL	2008	1	0	2	2	0	poor
2011.22T	HPL	2008	2	0	1	1	0	poor
2011.25T	PS	2010	1	10	68	78	13	poor
2011.25T	PS	2010	2	9	64	73	12	poor
2011.26T	PS	2010	1	0	67	0	0	poor
2011.26T	PS	2010	2	12	19	31	39	moderate
2011.29T	PS	2010	1	15	38	53	28	poor
2011.29T	PS	2010	1	48	0	48	100	good
2011.30T	PS	2010	1	0	39	39	0	poor
2011.30T	PS	2010	2	0	67	67	0	poor
2011.31T	PS	2011	1	81	0	81	100	good
2011.31T	PS	2011	2	76	0	76	100	good
2011.31T	PS	2011	3	83	0	83	100	good
2011.32T	PS	2011	1	67	0	67	100	good
2011.32T	PS	2011	2	31	0	31	100	good
2011.32T	PS	2011	3	55	0	55	100	good
2011.34T	PS	2011	1	60	0	60	100	moderate

2011.34T	PS	2011	2	53	0	53	100	good
2011.34T	PS	2011	3	45	0	45	100	good

[a] Although plot 710 was intended to represent the existing vegetation community, the site was overplanted with *Carex lenticularis* in 2011. As a result, the plot will now be tracked as a treatment plot.