Columbia River Project Water Use Plan

KINBASKET AND ARROW LAKES RESERVOIR REVEGETATION MANAGEMENT PLAN

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Kinbasket Reservoir Inventory of Vegetation Resources

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Monitoring Program No. CLBMON-10
Kinbasket Reservoir Inventory of Vegetation Resources




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Cover photos

From left to right: Common Horsetail Community in Bush Arm; woody debris accumulation on the Common Horsetail community at Beavermouth; Willow-Sedge community in the Valemount Peatlands; and Reed Canarygrass in Beavermouth. All photos © Virgil C. Hawkes, LGL Limited.

EXECUTIVE SUMMARY

2012 marked the fourth year of an anticipated ten year vegetation monitoring study of the vegetation communities occurring in the drawdown zone of Kinbasket Reservoir between 741 and 754 m above sea level (ASL). Initiated in 2007, the CLBMON-10 Kinbasket Reservoir Inventory of Vegetation Resources study is intended to address key uncertainties related to the relative contribution and importance of the current reservoir operating regime (i.e., timing, duration and depth of inundation, and multi-year stresses) on the maintenance of existing vegetation communities delineated at the landscape scale.

The primary objective of this study is to provide information on how vegetation communities at the landscape scale respond to long-term variations in water levels, and whether changes to the reservoir's operating regime may be required to maintain or enhance existing shoreline vegetation and the ecosystems it supports. The information gained through the inventory is also intended to assist in determining the scope of the Kinbasket Reservoir Revegetation Program Physical Works (CLBWORKS-1) by providing information on whether existing vegetated areas can be enhanced and expanded under the current operating regime. Similarly, efforts related to CLBMON-10 are aligned with CLBMON-9 Kinbasket Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis, and as such, there is significant potential for data sharing.

Through a combination of field data collection, aerial photograph interpretation, and statistical analyses, 19 vegetation communities have been delineated for the drawdown zone of the reservoir. With the exception of the two non-vegetated communities classified as "Driftwood" and "Wood Debris," the distribution and extent of those communities have not changed markedly since 2010, the most recent implementation year. Improvements associated with the acquisition of aerial photos in 2010 and 2012 resulted in a much-improved set of vegetation polygons, which can be used as the basis for future comparisons. The improvements resulted in the refinement of mapping produced in 2007 and an overall greater extent of mapping in 2012.

In 2012 the reservoir filled more rapidly than previous years, reaching full pool several weeks earlier. The reservoir also exceeded the normal operating maximum for the first time since 1997. The unusually early and deep flooding prevented timely worker access to all the areas that were earmarked for sampling, affecting our ability to draw meaningful comparisons between 2012 and other years. Nevertheless, the influence of reservoir operations on the structure and composition of vegetation communities was evident in 2012, with notable reductions since 2007 in species diversity and richness for communities occurring at the highest elevation of the drawdown zone and increases in diversity and richness for certain communities occurring lower down in the drawdown zone. These changes are attributed to the near filling of the reservoir in 2007 that resulted in the die-off of woody stemmed plants in the higher elevations and contributed (we believe) to the transport and settling of seeds at the lower elevations. We predict that these effects will have been further exacerbated by the return to near full pool levels in 2011, followed by the surpassing of the normal operating maximum in 2012. The extreme high water event of 2012 presents us with an additional opportunity in subsequent implementation years to track post-inundation impacts across all elevation bands

The timing and duration of inundation also influences the number of growing degree days (GGDs) available to vegetation in different zone of the reservoir. In the mid-

summer growing months of June, July, and August, there was a substantial reduction in the proportion of available growing days in 2007 and 2012 relative to 2008 and 2010, consistent with the full pool events in those years. It is difficult, without direct experimentation, to separate out the relative importance of wet stress and GGDs in modulating patterns of plant distribution and abundance on the landscape. Nevertheless, it is quite likely that the patterns of plant zonation within the reservoir have been set at least in part by prevailing GGDs, such that periodic reductions in GGDs (as seen in 2007 and 2012) may prove to be an important factor that ultimately limits the capability of certain vegetation communities to expand in spatial extent, or of new communities to become established.

Species constancy (the proportion of all species observed in 2012 that were also recorded in both 2007 and 2012) was rather low both for resampled transects and for whole communities, implying either that species compositions are fluid and apt to change from census period to census period (a possibility given the highly dynamic conditions), or that detectability rates for some species are low. Both are likely true to some degree. Ordination analyses (PCA and RDA) applied to vegetation and environmental data from sample transects were only moderately effective at recreating the original 2007 community classifications. Some of the disparities may be related to the rate at which the reservoir filled in 2012, which precluded sampling across many elevations, particularly those below 751 m ASL. While these results do not impugn the validity of using the vegetation communities defined in 2007 with the 2012 data, they do suggest that additional time series data are needed to further refine our picture of reservoir plant compositions. Changes to specific vegetation communities that are the consequence of reservoir operations may manifest into larger, landscape level changes that may only be determined after several more years of study.

The status of CLBMON-10 after Year 4 (2012) with respect to the management questions and management hypotheses is summarized in tabular form (below).

Management Question (MQ)	Management Hypotheses			Year 4 (2012) Status
i. What are the existing riparian and wetland vegetation communities in the Kinbasket Reservoir drawdown zone between elevations 741 m to 754 m?	H0			Vegetation communities (*n* = 19) have been characterized and mapped for the drawdown zone in each of 2007, 2008, 2010, and 2012. Improvements with aerial photographs continue to lead to refinements in the vegetation community mapping. This question is being addressed and the data will permit testing of the management hypothesis.
ii. What is the spatial extent, structure and composition (i.e., relative species distribution and diversity) of each of these communities within the drawdown zone between elevations 741 m to 754 m?		H_{0A}		Each vegetation community has been characterized relative to spatial extent (in a GIS), and metrics of species distribution (diversity and evenness) have been computed. The methods used to date will ensure that this management question is addressed and the specific management hypothesis tested. Longer time series of data are required prior to assessing the aforementioned metrics statistically.
iii. How do spatial extent, structure and composition of vegetation communities relate to reservoir elevation and site conditions (aspect, slope and soil drainage)?		H_{0A}		The spatial extent of each vegetation community is determined during each year of CLBMON-10 using a GIS. We have developed a predictive tool that relates vegetation community to elevation and substrate. Because sampling in 2012 was constrained by unusually high water levels, we currently lack the time series of data required to test for differences in the spatial extent, structure, and composition of vegetation communities with respect to site conditions such as aspect, slope, and soil drainage, With another year of field data, we can begin assessing these relationships.
iv. Does the current operating regime of Kinbasket Reservoir maintain the spatial extent, structure and composition of existing vegetation communities in the drawdown zone?	H0	H_{0A}	H_{0B}	We began to address this management question in 2010. The results of the 2012 sampling lent support to certain hypotheses we put forward in 2010. Because of the limited sampling that occurred in 2012 (due to unusually high water levels), another round of sampling (at a minimum) is required to validate our hypotheses related to how the operating regime affects the spatial extent, structure, and composition of existing vegetation communities. With another year of field data, we can test all of the hypotheses associated with this management question.
v. Are there operational changes that can be implemented to maintain existing vegetation communities at the landscape scale more effectively?	H0	H_{0A}	H_{0B}	The results of the first four years of sampling suggest there have been subtle impacts to the spatial extent, structure, and composition of existing vegetation communities resulting from reservoir operations. There are likely operational changes that can be implemented to maintain the existing vegetation community, but those changes need to be evaluated with respect to their feasibility. More work is required to address this management question and test the associated hypotheses.

H0: Under the current operating regime, there is no significant change in existing vegetation communities at the landscape scale in the drawdown zone of Kinbasket Reservoir over the monitoring period.

H_{0A}: There is no significant change in the spatial extent (number of hectares) of vegetation communities within the existing vegetated zones of Kinbasket Reservoir.

H_{0B}: There is no significant change in the structure and composition (i.e., species. distribution and diversity) of vegetation communities within the existing vegetated zones of Kinbasket Reservoir.

KEYWORDS: Kinbasket Reservoir; vegetation community; spatial extent; composition; diversity; distribution; monitoring; drawdown zone; landscape level; air photos; operating regime; reservoir elevation.

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1.0 INTRODUCTION

Dams regulate the water flow regime of over half of the world's large river systems (Nilsson *et al.* 2005). Flooding and flow alteration resulting from reservoir impoundment creates a complex disturbance that can modify entire ecosystems, with effects extending upstream and downstream of the dam (Nilsson *et al.* 1991; Hill *et al.* 1998; Luken and Bezold 2000; Van Geest *et al.* 2005, Poff and Zimmerman 2010, Ye *et al.* 2012a). The upstream effects of dam construction and water storage include inundation of streams and floodplains, trapping of river-transported sediment, alteration of soil nutrients, loss of intermittently flooded wetlands, and creation of new foreshore vegetation types (Petts 1979; Nilsson and Keddy 1988; Maheshwari *et al.* 1995, Roelle and Gladwin 1999; Nilsson and Berggren 2004; Beauchamp and Stromberg 2008, Wang *et al.* 2012, Ye *et al.* 2012a, b). Inundation can decrease plant diversity (Crossle and Brock 2002, Brock *et al.* 2005, Cherry and Gough 2006, Roberston and James 2007) and lead to altered plant assemblages (Casanova and Brock 2000, Baldwin *et al.* 2001, Crossle and Brock 2002, Warwick and Brock 2003, James *et al.* 2007, Hopfensperger and Engelhardt 2008, Kenow and Lyon 2009, Middleton 2009, Ye *et al.* 2012a).

Studies of riparian and wetland systems show that the individual components of water flow regime (e.g. flood depth, duration, frequency, and timing) affect plant performance measures and plant community development in specific ways (Casanova and Brock 2000, Greet *et al.* 2011, Webb *et al.* 2012). For example, increasing the depth of inundation decreases belowground biomass (though not total biomass, due to compensatory increases in shoot length; Hudon 2004, Edwards *et al.* 2003, Carillo *et al.* 2006), shoot density (Mauchamp *et al.* 2001, Sorrell *et al.* 2002), and reproductive output (Warwick and Brock 2003, Ishii and Kadono 2004), and alters plant assemblages (Hudon 2004, Van Geest *et al.* 2005, Watt *et al.* 2007, Della Bella *et al.* 2008, Wilcox and Nichols 2008). The seasonal timing of inundation affects plant establishment and diversity (Robertson *et al.* 2001, Budelsky and Galatowitsch 2004), as well as waterborn dispersal (hydrochory), reproductive output, germination and growth, and plant composition (Greet *et al.* 2011). The duration of flooding affects plant composition (Mawhinney 2003, Nicol *et al.* 2003, Auble *et al.* 2005, Cherry and Gough 2006, Della Bella *et al.* 2008), with some indication that increased duration may also negatively impact establishment (Nicol and Ganf 2000, Nishihiro *et al.* 2004, Takagawa *et al.* 2005, Banach *et al.* 2009) and plant diversity (Casanova and Brock 2000, Warwick and Brock 2003, Nishihiro *et al.* 2004, Raulings *et al.* 2009). Competition between species with differing tolerance for inundation may also modulate assemblage-level effects of flooding (Lenssen and De Kroon 2005, Banach *et al.* 2009), as can the exposure and slope of a flooded site (Keddy 1985, Luken and Bezold 2000).

Much of the research on water regime influence to date has focused on impacts to wetland systems (Greet *et al.* 2011). Less is known about the influence of dam operations on other structural and functional components of regulated river floodplains, such as the terrestrial and semi-terrestrial plant communities that establish on reservoir shorelines within the zone of water level fluctuation (i.e. the "drawdown zone"). In particular, the long-term influence of reservoir operating regimes on the establishment, persistence, or change in shoreline vegetation communities of reservoirs managed for electricity production has received little study (Wang *et al.* 2012).

While natural flood events are generally short-lived and often occur infrequently across time, reservoirs managed for power production have frequent water level changes, with a magnitude of change much greater than that expected during a natural flood event. These drawdown zones, which undergo alternating flooded and dry phases, are often highly dynamic, ruderal environments that bear little resemblance to the habitat that was in place prior to water impoundment (such as valley bottom habitat or forested valley slopes). Because of the unique challenges they present to plant establishment and growth, large portions of drawdown zones remain sparsely or sporadically vegetated, or devoid of vegetation altogether (Hawkes and Muir 2008). Where conditions support plant establishment, hydrological gradients or microtopographic relief can produce strong patterns of community zonation, resulting in a mosaic of community types that includes wetland vegetation, littoral communities, ruderal forb communities, sedge and graminoid communities, shrub and treed communities, and barren ground (Luken and Bezold 2000, Enns *et al.* 2009, Yazvenko *et al.* 2009, Hawkes *et al.* 2010). Through a combination of field data collection, aerial photograph interpretation, and ordination analyses, Hawkes *et al.* (2010) identified 19 distinct vegetation community types representing over 250 vascular plant species and covering nearly 3,000 ha of drawdown zone habitat in the Kinbasket Reservoir. The adjoining Arrow Lakes Reservoir, part of the same reservoir system on the Columbia River, supports 16 distinct drawdown zone community types, each predicted by a unique combination of substrate type, physiography, and elevation band within the drawdown zone (Enns *et al.* 2009).

Although the area covered by drawdown zones can be vast, amounting to hundreds of square km of floodplain and shoreline (Lu *et al.*2010), we do not yet have a good understanding of how reservoir operations influence patterns of community structuring at the landscape scale (Zhao *et al.* 2007, Enns *et al.* 2008, Hawkes and Muir 2008, Hawkes *et al.* 2010). As with wetland plants, upland and riparian species occupying reservoir foreshore communities are likely to differ in their levels of tolerance and affinity to inundation (Blanch *et al.* 1999, Lu *et al.* 2010), and also in plasticity of response (Vervuren *et al.* 2003, Luo *et al.* 2007). Flood-sensitive species may be largely restricted to higher regions of the floodplain where the impacts of flooding are reduced, while more tolerant species may persist at lower sites where flooding is more frequent or prolonged (Ye *et al.* 2012a). Extreme flooding events have the potential to determine the distribution of species along natural freshwater flooding gradients for many years (Vervuren *et al.* 2003), and the same likely holds true for reservoir foreshores (Hawkes *et al.* 2010). Likewise, current plant distributions probably reflect the history of changing water levels rather than the water levels near the time of survey (Tabacchi 1995, Vervuren *et al.* 2003).

Here, we report results at the four-year mark of a planned 10-year investigation of plant community dynamics in the Kinbasket Reservoir, an impoundment of the Columbia River located in southeastern British Columbia. Reductions in water surface elevation during the winter and early spring is a common dynamic in the operation of many storage reservoirs used for hydroelectric generation. In British Columbia, the magnitude of this annual drawdown cycle is often amplified because of steep valley morphology and reduced inflows during winter months. Water level elevations of Kinbasket Reservoir are managed under a regime that permits a normal annual minimum of 707.41 metres above sea level (m ASL) and a normal maximum of 754.38 m ASL—a difference of 46.97 m. In addition to this rather large (possible) annual variation, water levels change daily throughout the growing season. The resulting stress on vegetation within the drawdown zone is exacerbated by rates of deposition and erosion that are atypical of flooding events on shoreline habitats associated with unregulated lakes or rivers. Because of these extreme growing conditions, much of the foreshore is denuded of vegetation (Moody and Carr 2003). The present study is one component of a broader research effort to address the cumulative impacts of water regime management on shoreline plant communities, in light of recent recognition of the value of such vegetation in improving aesthetic quality, controlling dust storms that degrade air quality, protecting cultural heritage sites from erosion and human access, and enhancing littoral productivity and wildlife habitat (BC Hydro 2005).

We monitored landscape-level changes in plant community structure and composition, as well as the spatial extent of those communities, within a specified elevation band of the drawdown zone of Kinbasket Reservoir under the standing operating regime over a five-year period (2007–2012). The elevation band identified for monitoring ranged from 741 m to 754 m ASL and was selected because it overlaps with areas selected for revegetation as part of Kinbasket Reservoir Revegetation Program (CLBWORKS-1; BC Hydro 2005). The goal of CLBWORKS-1 is to maximize vegetation growth in the drawdown zone in areas that have good potential to become self-sustaining after five years. The lower elevation of 741 m was identified as the likely lower limit for successful vegetation establishment.

Our primary objectives were: (1) to assess the relative contribution and importance of the current reservoir operating regime (i.e., timing, duration, and depth of inundation, and multi-year stresses) on the maintenance of existing plant communities delineated at the landscape scale; (2) to provide information on how plant communities at the landscape scale respond to long-term (i.e., annual and inter-annual) variations in water levels; (3) to determine if changes to the reservoir's operating regime are needed to maintain or enhance existing shoreline vegetation and the ecosystems it supports; (4) to assist in ongoing revegetation efforts by providing information on whether existing vegetated areas can be enhanced and expanded under the present operating regime.

2.0 MANAGEMENT QUESTIONS AND HYPOTHESES

2.1 Inventory of Vegetation Resources

The vegetation inventory and monitoring program is intended to assess the relative contribution and importance of the current reservoir operating regime (i.e., timing, duration and depth of inundation, and multi-year stresses) on the maintenance of existing vegetation communities delineated at the landscape scale. The primary objective of this study will be to provide information on how vegetation communities at the landscape scale respond to long-term (i.e., annual and inter-annual) variations in water levels, and whether changes to the reservoir's operating regime may be required to maintain or enhance existing shoreline vegetation and the ecosystems it supports.

If results of the monitoring indicate that the operating regime does not adequately maintain the vegetation communities and their associated fauna at the landscape-level, future decisions regarding reservoir operations may be affected because of the high value placed on vegetated shorelines by many interest groups. The information gained through the inventory is also intended to assist in determining the scope of CLBWORKS-1 by providing information on whether existing vegetated areas can be enhanced and expanded under the present operating regime.

2.2 Management Questions

The primary management questions to be addressed by this study are:

1. What are the existing riparian and wetland vegetation communities in the Kinbasket Reservoir drawdown zone between elevations 741 m to 754 m?
2. What is the spatial extent, structure and composition (i.e., relative species distribution and diversity) of each of these communities within the drawdown zone between elevations 741 m to 754 m?
3. How do spatial extent, structure and composition of vegetation communities relate to reservoir elevation and site conditions (aspect, slope and soil drainage)?
4. Does the current operating regime of Kinbasket Reservoir maintain the spatial extent, structure and composition of existing vegetation communities in the drawdown zone?
5. Are there operational changes that can be implemented to maintain existing vegetation communities at the landscape scale more effectively?

2.3 Management Hypotheses

The primary hypothesis to be tested by this monitoring program is whether the current reservoir operating regime maintains existing vegetation communities at the landscape scale within the drawdown zone of Kinbasket Reservoir.

The management hypothesis and sub-hypotheses to be tested directly with the proposed monitoring program are:

H_0: Under the current operating regime, there is no significant change in existing vegetation communities at the landscape scale in the drawdown zone of Kinbasket Reservoir over the monitoring period.

H_{0A}: There is no significant change in the spatial extent (number of hectares) of vegetation communities within the existing vegetated zones of Kinbasket Reservoir.

H_{0B}: There is no significant change in the structure and composition (i.e., species. distribution and diversity) of vegetation communities within the existing vegetated zones of Kinbasket Reservoir.

2.4 Key Water Use Decision

The key operating decision affected by this monitoring program is the current operating regime for Kinbasket Reservoir. The decision of the WUP CC to support the current regime was based on the assumption that existing vegetation conditions could be maintained over the long term. This study will provide an assessment of the effectiveness of the current operating regime at maintaining the existing riparian and wetland vegetation communities and associated ecosystems at the landscape scale. Furthermore, by improving the understanding of how vegetation responds to variations in water level over time, the program will provide information to support future decision-making around retaining the current operating regime versus modifying operations (e.g., adjusting minimum or maximum elevations) to maintain and enhance vegetation communities in the drawdown zone.

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 powerhouse has a generating capacity of 1,805 MW. 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. Kinbasket Reservoir is 216 km long and has a licensed storage volume of 12 MAF[1] (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 (Figure 3-1; 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.

[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 by 660 feet then 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.

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

Zone Code	Zone Name	Subzone & Variant	Subzone/Variant Description	Forest Region & 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*	Interior Cedar – Hemlock	vk1	Mica Very Wet Cool	Nelson Forest Region (Columbia Forest District)
ICHmk1*	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)

* Not in all landscape units sampled

3.1 Physiography[2]

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 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 km2.

The Columbia River valley floor elevation falls 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., 2007–2012) occurring on both the east and west sides of the reservoir.

[2] From BC Hydro 2007 after BC Hydro 1983.

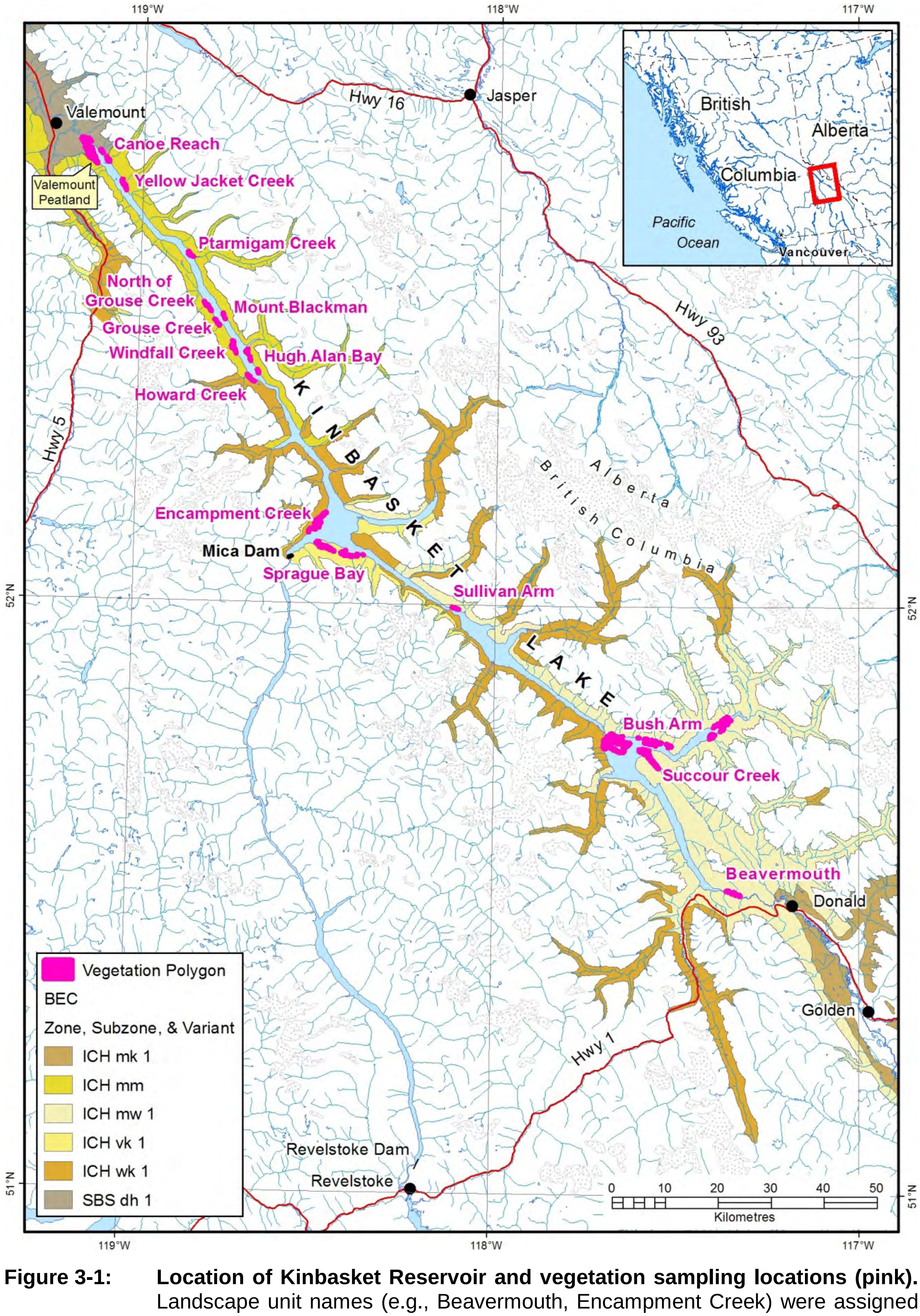


Figure 3-1: Location of Kinbasket Reservoir and vegetation sampling locations (pink). Landscape unit names (e.g., Beavermouth, Encampment Creek) were assigned to each area sampled in 2007. Pink areas also denote the locations of aerial photograph acquisition

3.2 Climatology[3]

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 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 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 2000m through the month of May and continue to contribute runoff long after the snow pack has 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.

4.0 METHODS

The study design follows Hawkes *et al.* (2007), Hawkes and Muir (2008), and Hawkes *et al.* (2010). The present study is a longer-term monitoring program, spanning a period of ten years (2007–2016). During years 1, 2, 4, 6, 8, and 10, aerial photograph interpretation and field sampling will be used to characterize vegetation communities within the drawdown zone of Kinbasket Reservoir between 741 m and 754 m ASL. The changes in spatial extent, structure, and species composition (defined as diversity and distribution) of each vegetation community are assessed in relation to sampling interval and to the following:

1. the annual operating regime of the reservoir (including woody debris removal);
2. the cumulative (temporal) effects of the operating regime;
3. Wet stress and dry stress (periods of inundation and exposure); and,
4. Non-reservoir effects (e.g., wildlife use, human-related impacts; environmental conditions).

The following specific questions are addressed:

[3] From BC Hydro 2007 after BC Hydro 1983.

1. Do the composition and/or spatial configuration of vegetation communities found within each elevation strata in the drawdown zone change over the 10 year duration of this study?
2. If a change is detected, can it be attributed to the current operating regime of the reservoir? Specifically, can it be attributed to inundation depth, frequency and duration (while controlling for potentially confounding variables such as climate, human and wildlife use, and topography)?

4.1 Definitions

Several definitions are required to ensure that the terminology used in this report is understood. Definitions are presented in logical, not alphabetical, order.

Vegetation Communities – plant assemblages characterized by specific species composition and per cent cover. Vegetation communities are delineated into vegetation polygons. Includes definition of dominant species

Vegetation Polygons – discrete vegetated areas of the drawdown zone that delineate vegetation communities visible in the aerial photography. The boundaries of some polygons are fluid, often shifting annually, which presents challenges for assessing change in those communities over time. Vegetation polygons are sampling and statistical units in various analyses to address management questions

Control Polygons – areas within vegetation polygons excluded from revegetation treatments (i.e., no revegetation prescriptions will be applied as part of CLBWORKS-1) to serve as statistical controls for the revegetation monitoring (CLBMON-9), and other monitoring programs that are occurring in the drawdown zone of Kinbasket Reservoir (e.g. CLBMON-11A - Wildlife Effectiveness Monitoring of Revegetation in Kinbasket Reservoir). See Section 4.4 for selection of control polygons in the drawdown zone of Kinbasket Reservoir.

Reference Sites – sites in the drawdown zone of Kinbasket Reservoir that are believed to have reached their climax state with respect to vegetation cover and distribution. No revegetation prescriptions are planned for these sites.

Landscape Units – the geographic areas where mapped vegetation communities occur within the reservoir (e.g., Bush Arm)

Transects – sampling units for obtaining field (or ground-truthing) data within each experimental unit. A transect is 20 m long X 0.5 m wide. Vegetation data are collected from ten 2 m X 0.5 m plots along the transect; these ten plots are then pooled for each transect to generate the sample (after Hawkes *et al.* [2007]; Hawkes and Muir [2008]; and Hawkes *et al.* [2010]).

Statistical Population – total number of vegetation polygons delineated in the drawdown zone of Kinbasket Reservoir between 741 m and 754 m ASL. The polygons delineated in 2007 (Hawkes *et al.* 2007) are considered the baseline population against which all comparisons will be made. The baseline population will be modified as new information is made available (i.e., the base condition will be scrutinized each year and any errors to the original delineation corrected).

Experimental Unit (EU) – vegetation polygons delineated at the landscape scale during each year of vegetation mapping. May or may not be equivalent to statistical population, depending on analyses performed and statistical units used.

Sample – selection of vegetation polygons or transects representing each community type (i.e., the experimental strata or ES) from which data will be collected to address management questions and hypotheses.

Statistical Units – vegetation polygons or transects, depending on the objectives pursued, that are used as statistical units to perform statistical analyses. Both polygons and transects are used in different analyses to address management questions.

4.2 Background

CLBMON-10 was initiated in 2007 with field sampling and aerial photography acquisition in years 1 and 2 (2007 and 2008) and year 3 (2010). The results of each of those years of study can be found in Hawkes *et al.* (2007), Hawkes and Muir (2008), and Hawkes *et al.* (2010). A brief overview of 2007, 2008, and 2010 findings is provided below.

4.3 Year 1 – 2007

In 2007, field work consisted of identifying and classifying vegetation communities within the drawdown zone between 742 m and 754 m ASL. The elevation range across which sampling occurred was stratified into 13 bands, each of which spanned 1 m in elevation (e.g., 741–742m ASL, 742–743 m ASL, etc.). Field Sampling occurred in 2007 and involved the establishment of 86 permanent transects in the drawdown zone of Kinbasket Reservoir. Vegetation data (species and per cent cover) were obtained from each transect, along with data on non-vegetated cover (e.g., rock and soil cover). Concurrent with field data collection was the delineation of discrete polygons defining different vegetation communities. Through the use of a cluster analysis on data obtained along each transect, we defined 15 vegetated communities and three non-vegetated communities in the drawdown zone of Kinbasket Reservoir (see Hawkes *et al.* 2007 and Table 4-1). Because field work started after the reservoir began filling, the lowest elevation band (band 1: 741–742 m ASL) was not accessible, so only elevations bands 2 through 13 were sampled in 2007 (i.e., between 742 and 754 m ASL). In addition to the vegetation sampling, we assessed all habitats covered by the aerial photographic surveys (22 flight lines) for wildlife use and suitability. With the exception of wildlife use and habitat suitability assessments, the methods used in 2007 were carried forward to 2008.

4.4 Year 2 – 2008

In 2008, all 13 elevation bands were sampled (i.e., 741 through 754 m ASL) and field sampling occurred at a number of transects established in 2007 (n = 45) and at newly selected transects (n = 31). The process for selecting transects to resample was non-random; transect selection was based on several criteria, including the level of effort applied to a given community in 2007 and the distribution of community types relative to the total area of each landscape unit. Consideration was also given to areas that are more easily accessed by vehicle and/or boat or that were poorly sampled in 2007 (see Hawkes and Muir 2008).

An arbitrary proportion (25 per cent) of all polygons of each vegetation community was selected as controls using the following random approach:

- The Statistical Population (consisting of all delineated polygons in the drawdown zone) was stratified first by landscape unit, then by vegetation community within each landscape unit.
- For each landscape unit, up to 25 per cent of each vegetation community mapped was selected by a random selection process (using a macro in MS Excel).
- If there was only one polygon of a given community in a geographic area, it was automatically selected.
- If there were two polygons of a given community in a geographic area, the first one in the list was selected.
- If > 2 polygons, and the first polygon selected was > 25 per cent of the total area of that community in that landscape unit, it was thrown out and a new polygon was selected (without replacement) until > 1 polygon were selected that together totalled ≤ 25 percent.
- If the first polygon selected was X, and the second polygon selected was Y such that X + Y ≥ 25 per cent, new polygons were selected until > 2 polygons were selected such that X + Y was ≤ 25 per cent. This process was repeated for a maximum of five times and the polygons selected after five iterations were selected as control polygons.
- Polygons in the Forest (FO) and Driftwood (DR) communities were removed from control polygon site consideration. The non-vegetated Wood Debris (WD) community was retained as it makes up a large portion of the Valemount Peatland and is one of the defining features of that area. Both the FO and DR communities are readily identified on aerial photos and can be easily mapped. FO communities occur outside of the drawdown zone and DR communities are likely to change annually as a function of reservoir elevation, prevailing winds, and the woody debris removal program.
- When a given vegetation community had only one polygon in a given landscape unit, it was removed from consideration if the same vegetation community occurred in the same Biogeoclimatic zone, subzone, and variant where polygons of the same vegetation community were already selected as control polygons using steps 4 through 6. A similar process was used for vegetation communities with only two polygons per landscape unit.
- A similar process was used for vegetation communities with only two polygons per landscape unit.
- When there were only two polygons and they could not be removed, the total area selected was often > 25 per cent. There were seven instances where 100 per cent of a vegetation community was selected as a control polygon (because it did not occur elsewhere in the same Biogeoclimatic zone, subzone, and variant). In one case (the Reed Canarygrass (RC) community), only one polygon was mapped for the entire reservoir in 2007.

4.5 Year 3 – 2010

Field sampling in 2010 followed the methods used in previous years. A total of 104 transects were sampled representing 14 vegetation communities and 12 landscape units. The only changes made were to the number of transects established in control polygons of each vegetation community, which were increased to balance the study design. Aerial photos were captured digitally in 2010 and the delineation of vegetation communities was done in both 2D and 3D using ArcGIS software or SoftCopy. The vegetation communities delineated in 2007 were used as a baseline for 2010 (mainly because the entire study area was not photographed in 2008). Similar and adjacent polygons were merged to create larger, continuous polygons representing a given vegetation community. The delineation of each community was also reassessed (given the enhanced quality of the photos) and a comparison of the spatial extent and distribution of vegetation in the drawdown zone was made between 2010 and 2007.

4.6 Year 4 – 2012

4.6.1 Vegetation Community Classification

We continued to use the same 16 vegetation communities and three ‘other’ (unclassified) communities characterized in 2007 and 2010 to map the vegetation communities in 2012 (Table 4-1). The vegetation community codes in Table 4-1 are used throughout this document.

Table 4-1: List of vegetation communities defined in the vegetated portion of the 13 m drawdown zone of Kinbasket Reservoir

Code	Common Name	Scientific Name	Drainage	SS[1]	Location
LL	Lady's thumb-Lamb's quarter	*Polygonum persicaria-Chenopodium album*	Imperfect to moderately w ell	2a	low est vegetated elevations
CH	Common Horsetail	*Equisetum arvense*	w ell	2a	above LL or low er elevation on sandy w ell drained soil
TP	Toad Rush - Pond Water-starw ort	*Juncus bufonius-Callitriche stagnalis*	imperfectly	2a	above LL, w et sites
KS	Kellogg's Sedge	*Carex lenticularis subspecies lipocarpa*	imperfectly to moderately w ell	2b	above CH
BR	Bluejoint Reedgrass	*Calamagrostis canadensis*	moderately w ell	2b	above CH, often above KS
MA	Marsh Cudw eed - Annual Hairgrass	*Gnaphalium uliginosum-Deschampsia danthonioides*	Imperfectly to moderately w ell	2a	common in the Bush Arm area
RC	Canary Reedgrass	*Phalaris arundinacea*	imperfectly to moderately w ell	2b	similar elevation to CO community
CO	Clover - Oxeye Daisy	*Trifolium spp.-Leucanthemum vulgare*	w ell	2a	typical just below shrub line and above KS
CT	Cottonw ood - Trifolium	*Populus balsamifera ssp. trichocarpa-Trifolium spp.*	imperfectly to w ell drained	3a,3b	above CO, below MC and LH
MC	Mixed Conifer	*Pinus monticola, Pseudotsuga menziesii, Picea engelmannii x glauca, Tsuga heterophylla, Thuja plicata*	w ell	3a,3b	above CT along forest edge
LH	Lodgepole Pine - Annual haw ks beard	*Pinus contorta-Crepis tectorum*	w ell to rapid	3a,3b	above CT along forest edge, very dry site
BS	Buckbean - Slender Sedge	*Menyanthes trifoliata-Carex lasiocarpa-Scirpus atrocinctus / microcarpus*	very poor to poor	2a	w etland association
WB	Wool-grass - Pennsylvania Buttercup	*Scirpus atrocinctus-Ranunculus pensylvanicus*	imperfectly to poor	2b	w etland association
SH	Sw amp Horsetails	*Equisetum variegatum, E. fluviatile, E. palustre*	poor	2a	w etland association
WS	Willow - Sedge w etland	*Salix - Carex* species	very poor to poor	3a,3b	w etland association
DR	Driftw ood	Long, linear bands of driftw ood, very little vegetation	n/a	n/a	w hole logs and large pieces of logs w ithout bark
WD	Wood Debris	Thick layers of w ood debris, no vegetation	n/a	n/a	typically small pieces similar to bark mulch
FO	Forest	Any forested community	varies	n/a	above draw dow n zone (>756 m ASL)

4.6.2 Vegetation Communities – Successional Stage and Predictability

To investigate how spatial extent, structure and composition of vegetation communities relate to reservoir elevation and site conditions (aspect, slope and soil drainage), we considered each vegetation community in relation to existing successional stage theory (Thomas 1979; Bunnell *et al.* 1999). Based on the most influential factors on vegetation communities in the drawdown zone (landscape unit, elevation, exposure (slope and aspect), soil moisture, soil texture and soil nutrients) and on factors for which there are empirical or categorical data (landscape unit, elevation, substrate), we developed a predictive tool that relates vegetation community to elevation and substrate (Hawkes et al. 2010). There are likely other variables that influence the occurrence of vegetation on the landscape, but we do not have empirical or categorical data for these.

In general, pioneering and early seral communities are those associated with lower elevations of the drawdown zone or which span a relatively large elevational gradient, and as such may be considered generalist, easily adaptable community types. In most cases, wetland or wetland-associated communities are included among the later-seral communities. Communities that contain tree species are considered later seral because they occur in regions of the reservoir that experience less frequent and shorter durations of inundation, thus allowing the establishment of woody vegetation. The classification of vegetation communities into a drawdown seral stage did not consider the non-vegetated communities or those that occur outside of the drawdown zone (e.g., the DR, WD, of FO communities). The successional stages associated with each of the communities characterized for the drawdown zone of Kinbasket Reservoir, from pioneering to late seral, are provided in Table 4-2.

Table 4-2: Proposed successional stage of the vegetation communities (VCC) delineated in the drawdown zone of Kinbasket Reservoir

VCC	Name	Successionla Stage
LL	Lady's thumb-Lamb's quarter	Pioneering
CH	Common Horsetail	Pioneering
TP	Toad Rush - Pond Water-starwort	Early
MA	Marsh Cudweed - Annual Hairgrass	Early
KS	Kellogg's Sedge	Early-mid
BR	Bluejoint Reedgrass	mid
RD	Common Reed	mid-late
CO	Clover - Oxeye Daisy	mid-late
WB	Wool-grass - Pennsylvania Buttercup	mid-late
SH	Swamp Horsetails	late-climax
BS	Buckbean - Slender Sedge	late-climax
WS	Willow - Sedge wetland	late
CT	Cottonwood - Trifolium	late
LH	Lodgepole Pine - Annual hawks beard	late
MC	Mixed Conifer	late

4.6.3 2012 Sampling Objectives

The objectives of the 2012 field sampling were: 1) to resample transects established in 2007, 2008, or 2010; and 2) to sample control polygons in each vegetation community. Field sampling was used to verify whether vegetation communities had changed over time. Field data were also used to verify the delineation of vegetation community polygons on the aerial photos obtained in 2012.

4.6.4 Field Sampling

Field methods followed those of Hawkes *et al.* (2007), Hawkes and Muir (2008), and Hawkes et al (2010). Because we were interested in monitoring vegetation at the landscape level and because polygons delineate vegetation communities, we continued to use the polygon as the experimental unit (see Section 4.1). All locations sampled in 2012 were of previously established transects.

Data were recorded onto forms adapted from those used in previous years (see Appendix 10-A). Photographs were taken of each transect and plot along each transect, including close-ups of plant species and general views of each transect and the surrounding vegetation community. Field sessions were timed to correspond with sampling in previous years (Figure 4-1). Vegetation sampling occurred during two field sessions: 11–21 June and 16–26 July (*cf.* 26–29 June and 10–18 July in 2007 and 18–25 June and 11–25 July 2008 and 14–23 June and 12–26 July 2010). In 2012, site access occurred via truck and walk-ins (e.g., Beavermouth, Bush Arm; Valemount Peatland, Ptarmigan Creek; Sprague Bay) or via Bell 206 helicopter (operated by Canadian Helicopters, Vernon, BC) (e.g., Encampment Creek, Grouse Creek, Mount Blackman, Hugh Alan Bay).

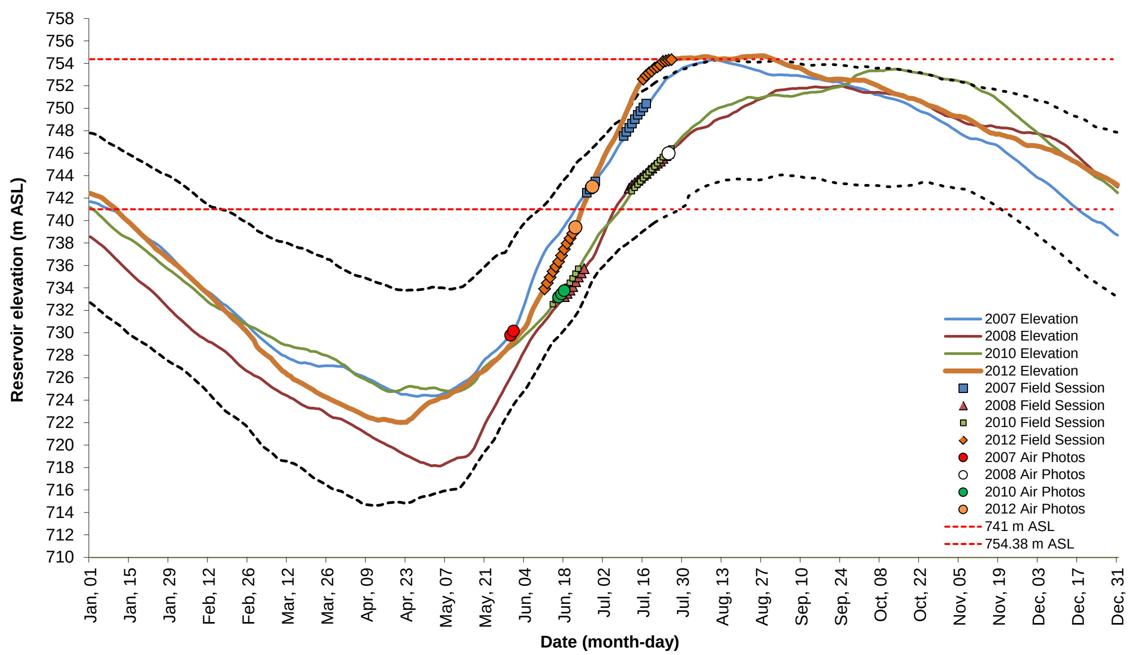


Figure 4-1: Kinbasket Reservoir elevations (m ASL) in 2007 (blue line), 2008 (red line), 2010 (green line) and 2012 (orange line). The horizontal dotted black lines indicate the 10th and 90th percentile. Timing of vegetation sampling (FS) and aerial photo (AP) acquisition is shown for each year.

Sampling locations were predetermined in the office using GIS. Sampling locations were selected to ensure that all landscape units and vegetation communities sampled in previous years were resampled in 2012. In 2012, we started with a selection of 108 transects representing 16 of the 19 vegetation communities defined for the drawdown zone of Kinbasket Reservoir. Because of rapidly rising reservoir levels, 78 of the 108 transects were sampled in 14 of the 19 vegetation communities (Table 4-3). At least one transect was sampled per vegetation community, with a maximum of 18 in the CH community, reflecting the greater amount of sampling that occurred in the lower elevation bands prior to inundation.

Table 4-3: Number of transects sampled per vegetation community code (VCC) and landscape unit. VCCs follow Hawkes *et al.* (2007) and are defined in Table 4-1. One transect was established per VCC within each landscape unit

	Landscape Unit												
2012 VCC	**Bush Arm**	**Canoe Reach**	**Encampment Creek**	**Grouse Creek**	**Hugh Alan Bay**	**Mount Blackman**	**North of Grouse Creek**	**Ptarmigan Creek**	**Sprague Bay**	**Sullivan Arm**	**Windfall Creek**	**Yellow Jacket Creek**	**Total**
BS	1												1
CH	1	2	2	1	1	3	2	2		2	1	1	18
CO		1				2							3
CT			4										4
DR		1					1						2
FO			1										1
KS			1		1		1	3	1				7
LL	2	4			1			4	1				12
MA	3												3
RC	1												1
SH	1	1											2
TP		1	1					1					3
WB	2	2	1						2				7
WS	1												1
NO*	2	2		1			1			1	1		8
Total	**14**	**14**	**10**	**2**	**3**	**5**	**5**	**10**	**4**	**3**	**2**	**1**	**73**

* Indicates transect situated in area devoid of vegetation.

Transect locations were located in the field using a hand held GPS receiver (Garmin GPSMap 60CSx). Previously established transects had been marked with capped re-bar and were generally easily relocated (V. Hawkes, pers. obs.). In some instances the rebar stakes could not be readily relocated, in which case UTM coordinates (recorded during establishment) were used to relocate the transect.

4.6.5 Aerial Photo Acquisition and Interpretation

In 2007, aerial photographs were taken on May 30 and 31 along 22 flight lines (Figure 4-1) over areas identified as having high or medium potential for vegetation enhancement (Moody and Carr 2003). The aerial photographs covered elevations from ~730 m ASL to > 754 m ASL (i.e., the entire area of interest for the study). In 2008, aerial photos were taken along the same 22 flight lines, and from an additional nine flight lines (31 total) to cover the areas of Sprague Bay and Esplanade Bay, and to expand the extent of coverage in others (e.g., portions of Beavermouth and Bush Arm; Figure 3-1). Due to weather delays in 2008, aerial photo capture occurred on July 25 when the reservoir elevation was 745.76 m ASL. As such, only elevations > 746 m ASL were photographed, limiting the area that could be mapped in 2008. However, because the reservoir went to full pool in 2007 for the first time in seven years, we felt it important to monitor changes to vegetation communities in the upper elevation bands (i.e., 746–754 m ASL). In 2010, aerial photography captured both the 2007 and 2008 mapped areas and the full elevation range (i.e., from 741 to 754 m ASL). The combined area was slightly larger than either the 2007 or 2008 area, resulting in a slightly larger mapped area for 2010 (see Section 0). The area photographed in 2010 was photographed again in 2012 on June 22 and 28. During this period inclement environmental conditions precluded the capture of aerial photos for some regions of the reservoir before the reservoir inundated the lower elevations of the drawdown zone.

In 2007 and 2008, aerial photographs were captured using analog cameras. In 2010, photos were captured digitally by Terrasaurus Aerial Photography Ltd. Terrasuarus photographed the drawdown zone in 2012 on June 16, 17, and 18 2010 between 10:30–12:30 and 13:30–15:30 each day to ensure optimum sun angles. Reservoir elevations ranged from 732.54 m ASL to 733.76 m ASL during photo acquisition. The aerial photography metadata are provided in Appendix 10-B.

4.6.6 Vegetation Community Polygon Delineation

Changes to the 2007 vegetation community polygons were made in 2010 to increase the accuracy and precision with which the vegetation polygons were delineated (see Hawkes *et al.* 2010). The refinement of the 2007 imagery in 2010 created a baseline dataset that can be used to assess changes in the spatial extent and distribution of vegetation communities in the drawdown zone of Kinbasket Reservoir.

The vegetation community polygons delineated in 2010 were updated to the 2012 orthomosaics using a heads-up (i.e., on screen) approach where each polygon delineated in 2010 was assessed relative to the 2012 imagery. Based on the visual comparison of 2010 to 2012, polygons delineated in 2010 were either left unchanged, modified to fit the extent of vegetation cover on the 2012 images, or deleted (if there was no vegetation on the ground). The spatial extent and distribution of each vegetation community delineated in 2012 was compared to the 2007 and 2010 datasets to determine whether substantive changes in the occurrence of extent of vegetation had occurred.

4.7 Statistical Analyses

4.7.1 Transect Data

The per cent cover of all vegetation species recorded over the ten quadrats sampled per transect were averaged to derive an estimate of total cover overall and per species for each transect. Hence, for this aspect of the study, the transect (not each quadrat) was used as the basic statistical unit in all analyses. General characteristics of the vegetation data sampled per landscape unit, elevation band, and vegetation community were described with a series of tables, graphs, and figures. Trends among vegetation communities, elevation band, and landscape units were based on three years of data (i.e., 2007, 2010, and 2012); data from 2008 were excluded from many analyses for reasons explained in the 2010 annual report (Hawkes *et al.* 2010).

Species constancy (previously termed "persistence" in Hawkes *et al.* 2010) was calculated as the proportion of all species recorded that appeared in each sample year (2007, 2010, 2012). Taxa not identified to species level (i.e., genus or family only) were not included in these analyses. Species constancy was first assessed in 2012, and then for transects sampled in all three years by elevation, landscape unit, and vegetation community. Species persistence relative to elevation was tested with a linear regression of type II, performed in the R language (version 2.15.2) and tested by permutations (9999 permutations). The number of unique species and frequency of species among vegetation communities was assessed visually via graphs.

Species richness, diversity and evenness were assessed over time by landscape unit, elevation, and vegetation community. Species richness was defined as the number of species occurring along transects, within vegetation communities, and for each landscape unit. To enable a comparison of species richness across vegetation communities and landscape units, species richness data were standardized by correcting for the unequal number of transects established within each vegetation community, landscape unit, and year by dividing the total number of species by the number of transects sampled. These methods are acceptable given the landscape scale of the study and given that we are not attempting comparisons of metrics such as biomass (see discussion in Forbes *et al.* 2001 and Weiher *et al.* 2004).

There are many ways to standardize richness (e.g., log of the number of individuals [Odum *et al.* 1960] or take 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 quadrats of equal size and used in conjunction with diversity indices that are dividing 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:

$$\mathbf{H = -\Sigma\ (pi\ log\ pi),}$$

where pi was 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 the species by transect, vegetation community, and landscape unit, Pielou's evenness was computed (Pielou 1966):

$$J = H/H_{max} = (-\Sigma\,(p_i \log p_i))/\log q, \text{ where } q \text{ is species richness}.$$

The more J tends towards 1, the more evenly the different species are distributed, and conversely, a value of J 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 communities, as well as the distribution of families within transects. For example, the diversity of a transect could be high, but its evenness index low, suggesting that although the transect has a high diversity of species of vegetation, one or two are dominating and the other species occur infrequently along transect (e.g., interspecific competition is high). However, the same high diversity index combined with a high evenness index would mean that the transect has a diversity of vegetation species that are equally frequent (e.g., interspecific competition is low).

Richness, diversity and evenness of vegetation according to landscape units, vegetation communities and elevation were summarized through box plots (Massart *et al.* 2005). Richness, diversity and evenness per transects were also computed per vegetation communities separately in three landscape units (Bush Arm, Canoe Reach and Encampment Creek). The vegetation communities in these landscape units were singled out because the majority of sampling in 2012 occurred in these units, which were also the most diverse (with respect to vegetation types) in both 2007 and 2010 (see Hawkes *et al.* 2007,Hawkes and Muir 2008, and Hawkes *et al.* 2010).

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-ways unbalanced analyses of variance (ANOVAs). ANOVAs were performed in the R language (version 2.15.2) and tested with 99,999 permutations. Vegetation communities or landscape units tested were only those with replicates for the two or three years. When a significant difference between 2007, 2010, and 2012 was found, a series of one-way ANOVAs were performed within each landscape unit, vegetation community or elevation band to find out where the significant difference was. The per cent cover of 37 dominant species in 2012 (those that occurred in > 2 communities, and that were not located in the middle of the ordination diagram based on their U scores) were used to assess whether the vegetation communities characterized for the drawdown zone of Kinbasket Reservoir in 2007 were still associated with the same dominant species in 2012.. A Principal Components Analysis (PCA) was used to represent the complex multidimensional data in a Euclidian, reduced space.

Community composition data, such as vegetation cover frequently contain a large number of zeros, which tends to produce highly positively skewed frequency distributions of the taxa abundances across sites (Legendre 2005). A transformation of these data is therefore necessary to make them suitable for statistical analyses using a PCA, which preserves Euclidian distances (Legendre and Gallagher 2001). Therefore, the first step of the analysis was to apply a Hellinger distance transformation to the relative abundance values calculated for each species detected within along each transect. The Hellinger transformation corresponds to taking the square root of the proportion of each taxa at each treatment (Legendre and Gallagher 2001). Scaling used to draw the ordination diagram was of Type II, which means that the angles between vectors approximate the correlation between variables. Projecting the vegetation communities at right angle onto a species vector also approximates the relative importance of that species in the given community. The ordination diagram will allow comparisons of associations of species and vegetation communities between 2012 and 2007.

Canonical analyses were performed to explore relationships between various characteristics of the vegetation and environmental, climatic and inundation variables over time. The form of canonical analysis used is an extension of multiple regression combined with an ordination technique. It involves a matrix Y, containing response variables of interest, constrained by a matrix X, containing independent variables. Direct comparisons allow one to directly test *a priori* ecological hypotheses by extracting all the variance of Y that is related to X, and conduct formal tests of these hypotheses (Legendre and Legendre 1998). Orthogonal axes are produced by canonical analyses, which enable the creation of scatter diagrams (or bi-plots).

Redundancy analysis (RDA) was also used, as it preserves the Euclidian distance in the ordination spaces and allows the computation of adjusted-R^2 (Legendre and Legendre 1998). The R^2 is the coefficient of determination of the multiple regressions embedded within the canonical analyses; it measures the fraction of variance in Y that is explained by a linear combination of the variables in X (Sokal and Rohlf 1995). The adjusted-R^2 (R^2a) is a modification of the R^2 that accounts for the number of explanatory variables included in the multiple regressions or canonical models. Increasing the number of explanatory variables in a model would automatically increase the R^2 even if the new variables do not improve the model more than would be expected by chance. In other words, any model containing as many variables as the number of data points can be adjusted to perfectly fit the data (Legendre and Legendre 1998). Using the adjusted- R^2 ensures that the proportion of variance of Y that is explained by the variables in X is not influenced by how many variables there are in X.

A reduction in the number of independent variables was made prior to the analysis using a forward selection procedure. Variable selection ensures that any variable that does not significantly contribute to the model (by increasing the R^2) is eliminated (Legendre and Legendre 1998). All techniques of variable selections have pros and cons, but forward selection was judged adequate to select meaningful variables, especially as the significance of the variables in the various models could be tested by permutations, thereby avoiding the problems of normality of the data. The forward selection procedure starts with no variables in the model, adding each variable one at a time until the largest increase in R^2 is provoked, provided that this increase is significantly different from zero. It continues until the addition of more variables does not produce a significant increase in R^2 (Legendre and Legendre 1998). The forward selection procedure avoids the inclusion of variables that do not significantly contribute to the models, hence artificially inflating the R^2 (but decreasing the degrees of freedom necessary to test their significance). It also allows the models to be simpler (i.e., the models comply with the parsimony principle), and generally easier to interpret.

The first RDA assessed differences in cover in 2012 among transects for 437 main species (present in more than 5 transects) in relation to environmental variables. The second RDA was similar, except that variables were summarized per vegetation communities instead of per transects. Different forward selections were performed for both RDAs. The covers of the species were transformed with the Hellinger distance to use Euclidian-based ordination methods such as RDA, while avoiding the problems associated with the Euclidian distances (Legendre and Gallagher 2001). Environmental variables included in the forward selection were substrate (cover of shrub, moss, herbs, live, decaying and dead organic matter, rock, and mineral soil), slope, heatload, and elevation. Substrate variables were estimated in the field for each quadrat and averaged per transects. Slope, aspect and elevation were derived in the office from GIS for each transect. Aspect was transformed to heat load in order to vary on a scale of 0 to 1 (McCune and Keon 2002). The formula applied was: $(1-\cos(\theta-45))/2$, where θ is the value of the aspect. All environmental variables were standardized prior to conducting the analyses, as the variables were not in the same physical units and dimensions (Legendre and Legendre 1998). The standardization was achieved by subtracting the mean and dividing by the standard deviation of the variable (Legendre and Legendre 1998). Multicollinearity among environmental variables was assessed with the variance inflation factors (VIF) prior to conducting the forward selection of the variables, and variables found to be highly correlated (VIF > 10, Zuur *et al.* 2007) were not included in the modeling.

Scaling was of Type II for all canonical analyses performed, which means that angles between vectors in the ordination reflect their correlations. Red vectors are the response (dependent) variables and blue vectors are explanatory (independent) variables. Dots represent qualitative explanatory variables. The projection of the qualitative variables at right angle on the vectors of response or explanatory quantitative variables also reflects their correlations. R^2 is the coefficient of determination of the multiple regressions and it measures the fraction of variance in Y explained by a linear combination of variables in X (Sokal and Rohlf 1995). The adjusted- R^2 is a modification of the R^2 that accounts for the number of explanatory variables included in the multiple regressions or canonical models. It is associated with a p-value (probability, tested with 99999 permutations) assessing the statistical significance of the canonical relationship. The contribution of the explanatory variables to the canonical axis is carried by the standardized canonical coefficients that give the weights of the variables X in the formation of the fitted site scores (that are plotted). These coefficients are usually not shown, but they can be visually approximated by the length of the vectors representing the explanatory variables: the longer one vector is along a given canonical axis, the more it contributes to this axis. Variables clustered at the middle of the ordination diagram are considered not to be contributing much to the canonical relations; they will usually be excluded from the models by the forward selection of the variables conducted prior to the canonical analyses. The information of interest is mainly expressed by the angles between the vectors of dependent and explanatory variables (in Type II scaling); the smaller the angle, the more correlated variables are. Vectors pointing in totally opposite directions suggest that the variables are inversely correlated.

4.7.2 Polygon Data

Most analyses applied to the transect data were also applied to the polygon data (i.e., vegetation community delineation) for the three years (2007, 2010, and 2012). The spatial extent of each vegetation community present at each landscape unit in each year was computed in a GIS. The richness of vegetation communities per landscape units corresponded to the number of vegetation communities recorded in each landscape unit over time. Diversity of vegetation communities per landscape unit was computed with the Simpson index of diversity. It corresponds to: 1-(Σ ni (ni-1))/ (N(N-1), where ni = cover of a vegetation community i and N= total cover of vegetation. A value close to 1 means high diversity, while a value close to zero means little diversity (Legendre and Legendre 1998).

Differences in spatial extent between years, landscape units and vegetation communities were assessed with unbalanced one and two-ways ANOVAs, performed in the R language and tested with 9999 or 99,999 permutations, respectively. A two-way ANOVA was used to test whether the spatial extent was different between years and among vegetation communities. One-way ANOVAs were used to assess whether there were differences in the spatial extent of vegetation communities within and between landscape units in 2007,2010, and 2012.

An RDA was performed with data derived from aerial photography interpretation. The amount of time the drawdown zone was exposed was computed per elevation in April 2007, 2010, and 2012. The analysis was performed for this month only because it was thought that it would be sufficient to use the beginning of the growing season at this stage of the study. April was used to provide an indication if all vegetation communities and elevation bands were exposed at the start of the growing season, and therefore each vegetation community would be able to develop over a similar period of time each year. The exposed area calculated for each elevation band was then related to inundation time and duration and to climatic variables to assess the influences of inundation and climate on vegetation communities occurring across the elevation gradient over time. Inundation variables used were depth, timing, frequency and duration, and were all derived for each elevation band and for April and September from reservoir elevation data supplied by BC Hydro. Water depth was calculated as the difference between reservoir elevation and the on-the-ground elevation (i.e., the elevation of each elevation band between 741 and 754 m ASL). The timing of inundation was assessed by determining when the reservoir elevation reached each elevation band after the start of the growing season (April 1). Frequency was computed as the number of times that the reservoir elevation exceeded each elevation band within each year. Finally, duration was computed as the number of days that vegetation communities occurring at each elevation band were exposed for each month between April and middle of October.

Climatic variables included in the model were temperature, precipitation and relative humidity. Temperature and relative humidity were averaged over each month for exposed vegetation, per elevation band. Precipitation was added up for each exposed elevation band, per month. Data were provided by the BC Ministry of Forests.

The type of analyses performed were identical to those performed using the transect data. Both dependent and independent variables were standardized prior to conducting the analyses. Multicollinearity among independent variables was assessed, and a forward selection was performed of the variables. All steps of the analyses were performed in the R language (version 2.15.2).

4.7.3 Climatic Data

Meterological data from two stations in the vicinity of Kinbasket Reservoir (Table 4-4) were obtained from the BC Wildfire Management Branch. These data sets were used to summarize temperature (°C), relative humidity (%) and precipitation (mm) for each reservoir. All summaries were done using MS Excel 2010.

Table 4-4: Meteorlogical stations accessed for weather data in 2012

Reservoir	Station Name	Latitude	Longitude	Elevation (m)
Kinbasket	Howard	52.37208	-118.66028	838
Kinbasket	Valemount Hub	52.86983	-119.29908	797

The program WRPlot View™ (Lakes Environmental[4]) was used to generate wind rose plots representing the predominant wind flow direction and speed in Kinbasket Reservoir for all implementation years (i.e., 2007, 2008, 2010, and 2012).

Unless stressed by other environmental factors like moisture, the development rate from emergence to maturity for many plants depends upon the daily air temperature. Because many developmental events of plants depend on the accumulation of specific quantities of heat, it is possible to predict when these events should occur during a growing season regardless of differences in temperatures from year to year. Growing degrees (GDs) are defined as the number of temperature degrees above a certain threshold base temperature. The base temperature is that temperature below which plant growth is zero. GDs are calculated each day as maximum temperature plus the minimum temperature divided by 2 (or the mean temperature), minus the base temperature. GDDs are accumulated by adding each day's GDs contribution as the season progresses.

GDDs can be used to assess the suitability of a region for vegetation production, to estimate the growth-stages of vegetation, or to estimate the heat stress on crops. GDDs could also be used to predict the best time to plant certain species of vegetation. In this case, we used the GDDs to assess the effects of reservoir inundation on the availability of GDDs for plant communities growing in the drawdown zone of Kinbasket Reservoir.

Growing degree days were calculated using the following formula

$$GDD = \frac{T_{max} + T_{min}}{2} - T_{base}$$

[4] http://www.weblakes.com/products/wrplot/index.html

Where GDD = Growing degree days, T_{max} = maximum daily temperature, T_{min} = minimum daily temperature, and T_{base} = a base temperature, which was set to 10°C for all calculations. The minimum temperature was set to 10°C for all instances where T_{max} or T_{min} were less than this value. Similarly, a maximum of 30°C was used because most plants do not grow any faster at temperatures > 30°C.

5.0 RESULTS

5.1 Vegetation Data – Transects

Since 2007, 172 transects have been sampled in the drawdown zone of Kinbasket Reservoir. The number sampled per year ranged from 73 in 2012 to 97 in 2010 (Figure 5-1A). The number of times that a given transect was sampled ranges from one to four. Eleven transects have been sampled in all four years; 42 in three of the four years, and 48 in two of the four years (Figure 5-1B). In 2012, 55 of the transects sampled in 2010 were resampled. This number was to be higher in 2012; however, we were unable to access many of the planned transects because of the rate at which Kinbasket Reservoir filled in 2012 (see Figure 4-1).

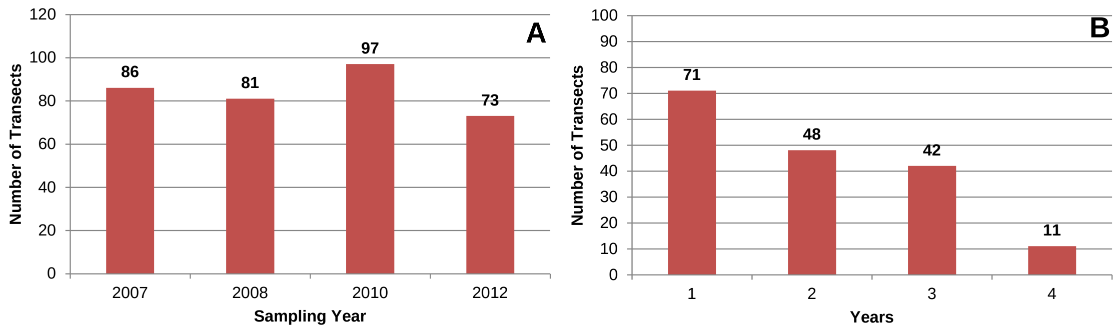


Figure 5-1: Number of transect sampled in the drawdown zone of Kinbasket Reservoir per year (A) and over consecutive years (B).

5.1.1 Species Constancy

Since 2007 we have recorded 291 species of vegetation in the drawdown zone of Kinbasket Reservoir. We documented a total of 198, 113, 186, and 159 plant species in 2007, 2008, 2010, and 2012 respectively (Figure 5-2). Differences in total numbers of plants per year can be partly attributed to reservoir elevations, especially in 2008 and 2012. Other differences are likely related to reservoir operations (see Hawkes *et al.* 2010). Forty five of these species were found only in 2009, four only in 2008, 22 only in 2010, and 42 in 2012 (Figure 5-2). One hundred seventeen species (~39 per cent) were documented in only one of the four years of sampling, 60 (~20 per cent) in two of the four years, 52 (~17 per cent) species in three of the four years, and 67 species (~23 per cent) were documented in all four years.

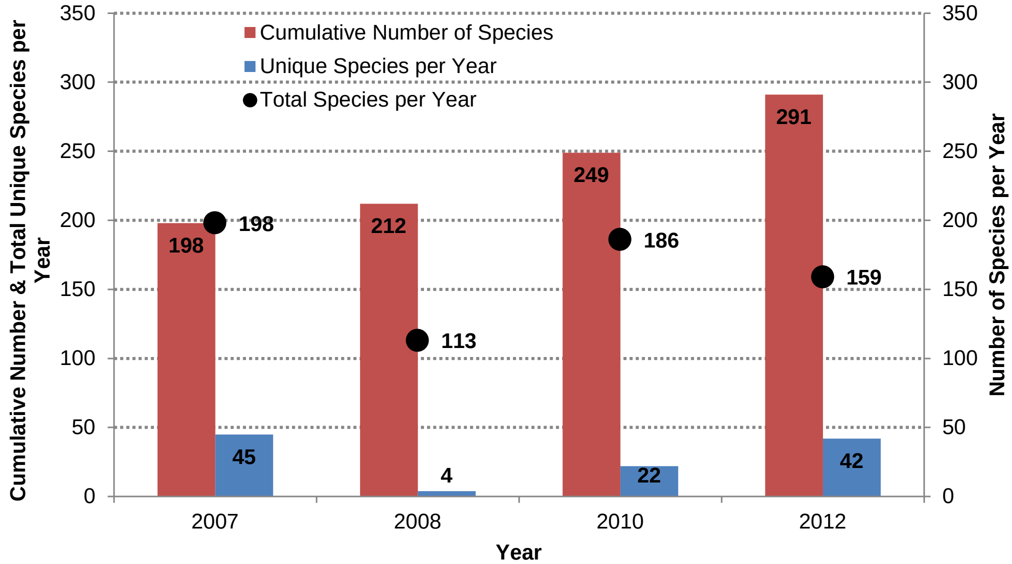


Figure 5-2: The cumulative number of vegetation species detected in the drawdown zone of Kinbasket Reservoir since 2007. The number of unique species and total number of species detected per year of sampling are also shown.

Species constancy was assessed for each transect sampled in 2007, 2010, and 2012 (n = 10; Table 5-1). A number of species were documented just once on a given transect, while some species recorded in 2007 went undocumented in 2010 before (apparently) reappearing in 2012. Species constancy (the proportion of all species observed that were documented in each year) ranged from a low of 17 per cent (transect 9 at Canoe Reach) where only one species (out of the six total observed) was documented along the same transect in all three years, to a high of 64 per cent (transect 60 at Ptarmigan Creek). In general, species constancy averaged 44 percent with a median of 50 per cent across transects.

Table 5-1: Species constancy along transects sampled over time in the Kinbasket Reservoir (2007, 2010, and 2012). Per cent constancy calculated as the proportion of all species present in 2012 that were recorded in all three years

Landscape Unit	Transect	Elevation (m ASL)	No. of species observed								% Constancy
			Total (all yrs)	2007 only	2010 only	2012 only	2007 & 2010	2007 & 2012	2010 & 2012	All 3 years	
Bush Arm	30	743.6	21	6	1	5	2	0	4	12	57
	79	749.1	11	6	3	4	0	1	3	3	27
Encampment Creek	21	744.5	8	12	1	1	0	2	1	4	50
	25	743.8	21	5	2	1	0	2	7	11	52
Grouse Creek	63	750.6	2	12	3	0	1	1	0	1	50
Mount Blackman	18	743.8	3	2	0	0	1	2	0	1	33
Ptarmigan Creek	60	748.3	11	7	5	2	4	1	1	7	64
Canoe Reach	6	746.1	17	0	3	7	0	1	3	6	35
	8	747.2	12	1	1	4	0	1	0	7	58
	9	746.9	6	3	2	0	2	1	4	1	17

In 2010, there was a strong negative relationship between species constancy (previously termed "persistence"; Hawkes *et al.* 2010) and elevation that is not seen again in 2012 (Figure 5-3). In 2012, constancy did not vary significantly with elevation, which might reflect the fact that no transects at the highest elevations (> 750m) were resampled in 2012.

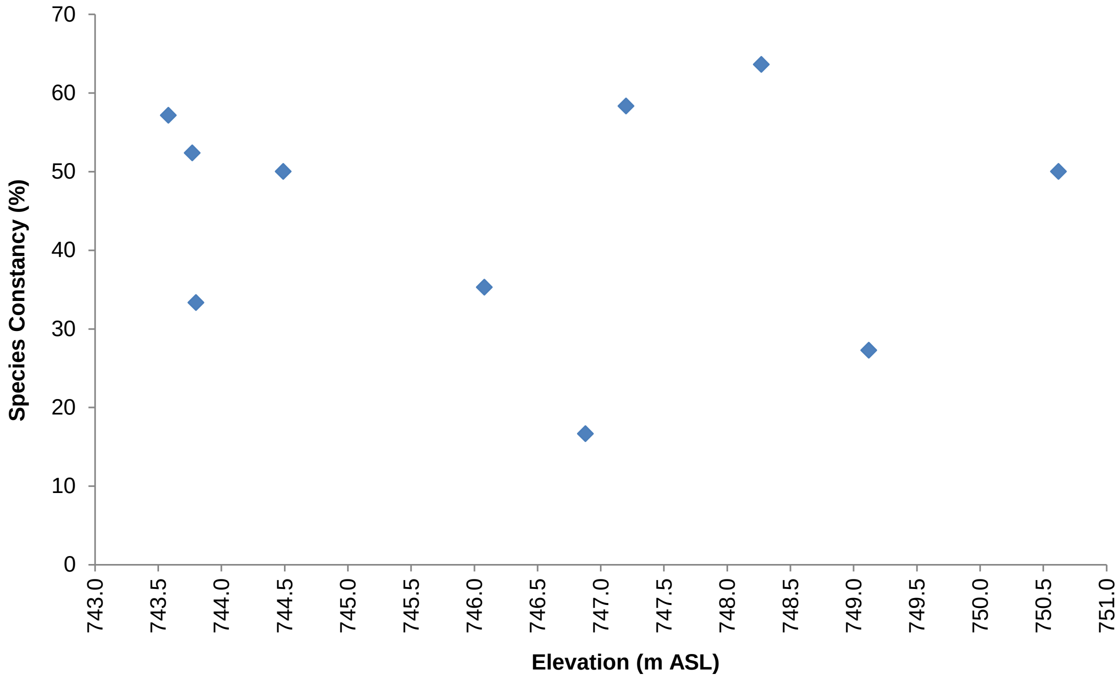


Figure 5-3: Plant species constancy (%) in resampled transect (*n* = 10) over the four years of sampling, in relation to elevation (m ASL). The relationship was not statistically significant ($p > 0.05$)

5.1.2 Vegetation Community Classification

Principal Components Analysis (PCA) was moderately successful at grouping species in ordination space in a way that aligned with the 2007 community classification (Figure 5-4), lending mixed support to the original classification. For example, the Swamp Horsetails community (SH) appears close in ordination space to Swamp Horsetail (EQUIFLU) and Marsh Horsetail (EQUIPAL) and to several other marsh wetland associates (e.g., Yellow Monkey Flower, MIMUGUT). The Toad Rush – Water-starwort community (TP) appears close to its namesake species, Toad Rush and Water-starwort spp. (CALLPAL). The Lady's-thumb–Lamb's-quarter community (LL) is close to Lady's-thumb (POLYPER), Purslane Speedwell (VEROPER), and Common Knotweed (POLYAVI), and somewhat close to Lambs-quarter (CHENALB). As expected, the Common Horsetail (CH) community is situated close to its namesake species (EQUIARV). On the other hand, a large number (over half) of communities (e.g. KS, BR, CO, WS) were not closely associated in space with their dominant or primary species. Several communities (e.g., RC, CO, BS, and BR) were clustered fairly close together in ordination space, emphasizing the fact that species compositions are generally somewhat overlapping. Some of these disparities may be related to the rate at which the reservoir filled in 2012, which precluded sampling across many elevations, particularly those below 751 m ASL.

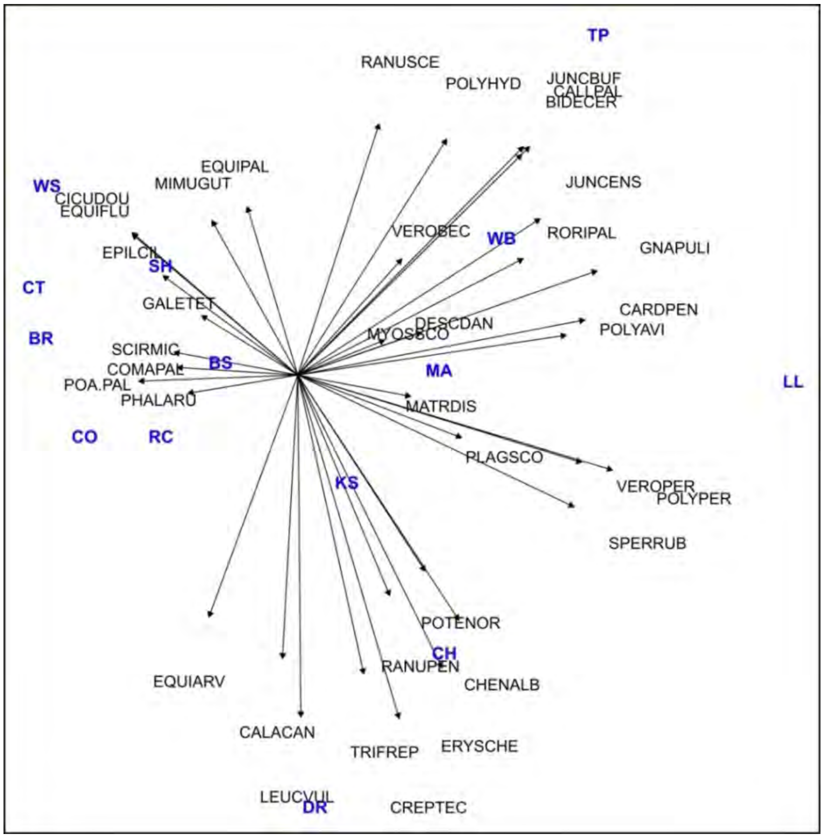


Figure 5-4: PCA diagram correlating the average per cent cover of the main species of vegetation associated with each vegetation community. Axis 1 explains 26 per cent and Axis 2, 16 per cent of the variation in species cover. Community codes (in blue) are expanded in Table 4-1

5.1.3 Species Richness of Vegetation Communities

Total species richness varied greatly among vegetation communities and over time (Figure 5-5). Woolgrass-Pennsylvania Buttercup (WB) communities, followed by Buckbean–Slender Sedge (BS) communities supported the highest number of species in all years, while Common Horsetail (CH) had the lowest richness in all years followed by Lady's thumb-Lamb's quarter (LL). Species richness values increased between 2007 and 2012 for three communities including BS, LL, Willow-Sedge wetland (WS), and Toad Rush-Pond Water Starwort (TP), but total richness decreased in all other vegetation communities.

Total species richness seemed to peak in the mid-seral and wetland-associated communities (WB, BS, WS) rather than in the early and late seral communities. This makes sense given the relative stability of wetland communities (See Section 6.0). In general, wetland communities occur at higher elevations (refer to Figure 5-17), which contributes to an increased level of stability.

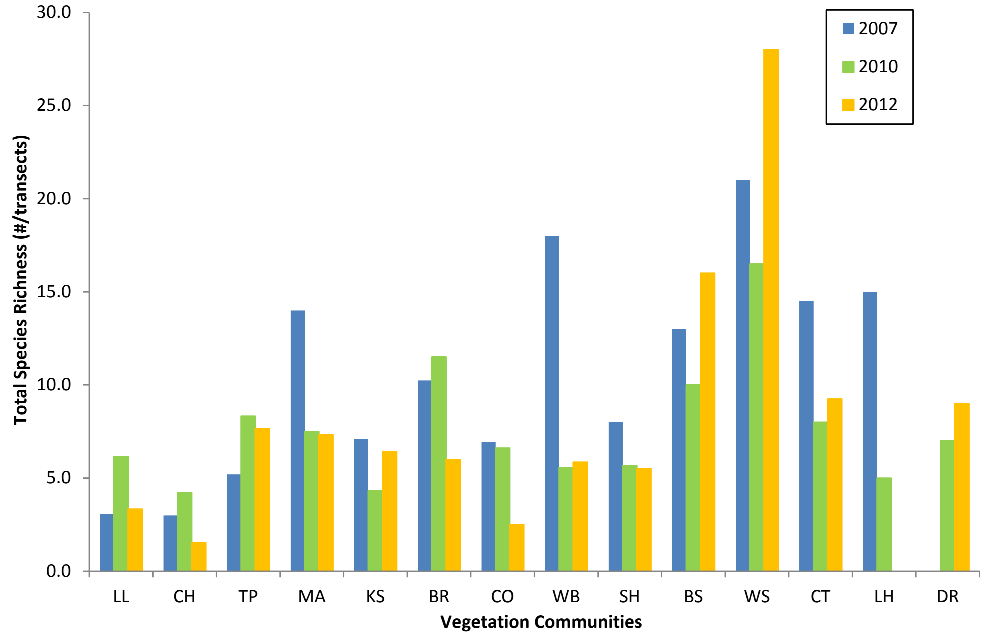


Figure 5-5: Total richness (number of species) per vegetation community in 2007, 2010, and 2012, corrected by the number of transects sampled in each year. Vegetation communities are ordered relative to seral stage, from pioneering to late seral communities. Refer to Table 4-1 for a description of the vegetation communities

5.1.4 Species Constancy within Vegetation Communities

Species constancy between 2007 and 2012 varied among communities (Table 5-2; Figure 5-6). The Toad Rush-Pond Water Starwort (TP) communty had the highest proportion of species recorded in all three years, followed by the Lady's-thumb–Lamb's-quarter community (LL). Species in the Marsh Cudweed-Annual Hairgrass (MA), Kellog's Sedge (KS), and Wool-grass-Penssylvania Buttercup (WB) communities were also relatively constant from 2007 to 2010. High species constancy in these communties, particularly the TP, LL, and MA communities, is likely related to several factors including elevation and topography. The TP, LL, and MA communities are situated relatively low in the drawdown zone. Consequently, the species likely to be found there are ones that can withstand a substantial amount of inundation. The WB community, on the other hand, was a more stable wetland-associated community, hence low species turnover is to be expected.

Table 5-2: Species constancy within vegetation communities sampled in 2007, 2010, and 2012. Note: different numbers of transects were sampled per communitiy in each year. Per cent constancy calculated as the proportion of all species present in 2012 that were recorded in all three years. Communities were ordered according to seral stage, from pioneering to late seral. Refer to Table 4-1 for community definitions

Vegetation Communities	No. of spp. observed					% unique to 2012	% Constancy
	Total: all yrs	2012 only	2007, 2010 and 2012	2007 and 2012	2010 and 2012		
LL	53	3	20	2	5	5.7	38
CH	86	3	14	0	9	3.5	16
TP	33	1	18	1	3	3.0	55
MA	36	4	9	6	3	11.1	25
KS	100	6	28	2	9	6.0	28
BR	71	3	9	2	4	4.2	13
CO	154	1	8	1	0	0.6	5
WB	52	9	14	1	17	17.3	27
SH	58	0	8	1	2	0.0	14
BS	37	8	6	0	2	21.6	16
WS	99	4	12	2	10	4.0	12
CT	99	21	10	2	4	21.2	10
LH	18	--	--	--	--	--	
DR	--	14	--	--	4	--	

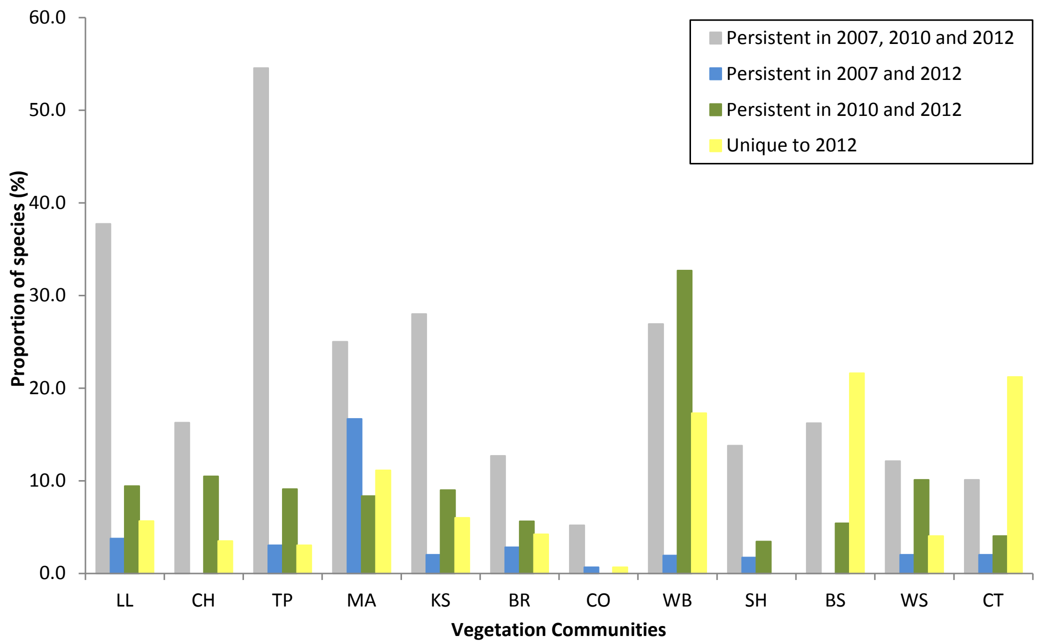


Figure 5-6: Species constancy per vegetation community from 2007 and 2010, and proportion of species unique to 2012. Vegetation communities were ordered per seral stage, from pioneering to late seral communities. Refer to Table 4-1 for a description of the vegetation communities

Most of the communities in the 744–749 m ASL range had relatively high species constancy (e.g., LL, TP, MA, KS, WB). Exceptions included CH (16 per cent), SH (14 per cent), and BS (16 per cent) (Table 5-3). Species constancy in the CH community may be low due to the dynamic nature of Kinbasket Reservoir and the annual (and likely seasonal) transport and deposition of sediment. Communities that occurred high in the drawdown zone, such as BR, CO, CT, and WS, tended to have a relatively low rate of species recurrence (ranging from five to 13 per cent). In the case of WS, this can be attributed to the filling of the reservoir to full pool in 2007 for the first time in seven years followed by the die-off of woody-stemmed vegetation. The general operation of the reservoir may also contribute to the lower species constancy (see Section 6.0).

Table 5-3: Species constancy across time relative to vegetation community and elevation. Two types of species constancy were computed: 1) C-1: proportion of species sampled in 2012 that were also seen in at least one previous year (2007 or 2010) (black); and 2) C-2: proportion of species sampled in 2012 that were seen in all three years (grey). The size of the filled circle represents the proportion, with large circles indicating a higher proportion. Refer to Table 4-1 for plant communities. Vegetation communities were ordered per seral stage, from pioneering to late seral communities

	LL		CH		TP		MA		KS		BR		CO		WB		SH		BS		WS		CT	
Elevation (m ASL)	C-1	C-2	C-1	C-2	C-1	C-2	C-1	C-2	C-1	C-2	C-1	C-2	C-1	C-2	C-1	C-2	C-1	C-2	C-1	C-2	C-1	C-2	C-1	C-2
741	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
742	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
743	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
744	37.7	94.3	0	0	54.5	97	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
745	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
746	0	0	0	0	0	0	25.0	88.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
747	0	0	16.3	96.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
748	0	0	0	0	0	0	0	0	28.0	94	0	0	0	0	26.9	82.7	13.8	100	0	0	0	0	0	0
749	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16.2	78.4	0	0	0	0
750	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
751	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
752	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
753	0	0	0	0	0	0	0	0	0	0	12.7	95.8	5.2	99.4	0	0	0	0	0	0	0	0	0	0
754	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10.1	78.8
755	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
756	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
757	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12.1	96	0	0

The largest number of unique species (i.e., sampled in only one community) was associated with the Willow-Sedge wetland (WS) community, which had > 20 unique species in 2012; for all other communities, the number of unique species was low (< 4 species per community; Figure 5-7). The high number of unique species in WS may reflect its transitional position near the top of the drawdown zone and structurally diverse composition that includes a speciose willow and shrub assemblage not found at lower elevations. Alternatively, this could reflect the fact that only one transect was sampled in 2012, compared to three to four in other years, so the result may be biased. Over time, the number of unique species increased in the WS, Kellog's Sedge (KS), and Cottonwood-Trifolium (CT) communities, but was declining in most of the other communities (Figure 5-7). If the number of unique species remains constant over time (or changes) we can say something about the stability of those communities relative to reservoir operations, and over time (e.g., after 2012) we can start to address portions of management questions two and three.

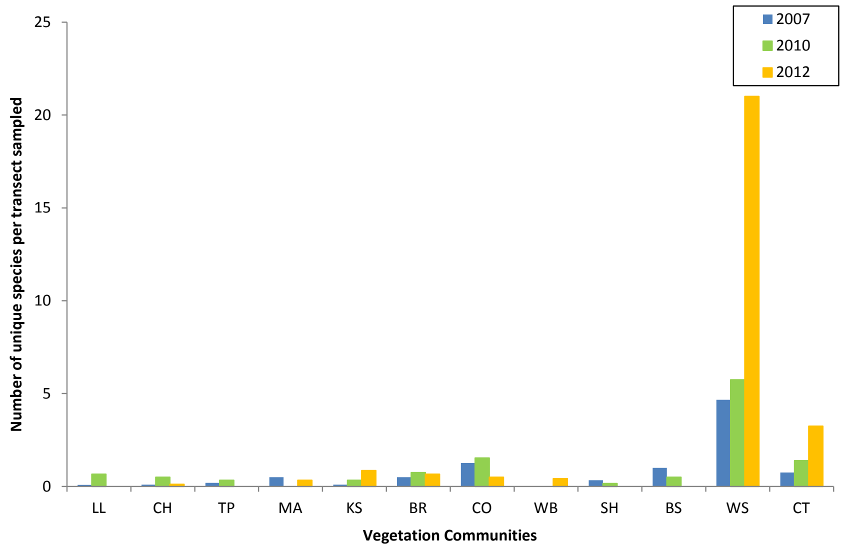


Figure 5-7: **Number of species unique to each vegetation community over time, corrected for the number of transects sampled each year.** Vegetation communities were ordered according to seral stage, from pioneering to late seral communities. Refer to Table 4-1 for vegetation community codes

Two plant species were observed, with various covers and frequencies, in almost all communities in all three years: Common Horsetail (*Equisetum arvense*) and Kellogg's Sedge (*Carex lenticularis* ssp.*lipocarpa*). However, few species occurred in more than seven communities, and most species (> 65 in 2012) were found in just one or two communities (Figure 5-8). A similar pattern has been reported in other reservoirs (Enns *et al.* 2008, 2009) and appears to be independent of the total species documented in a given year (2007: 199 species and 2010: 186 species).

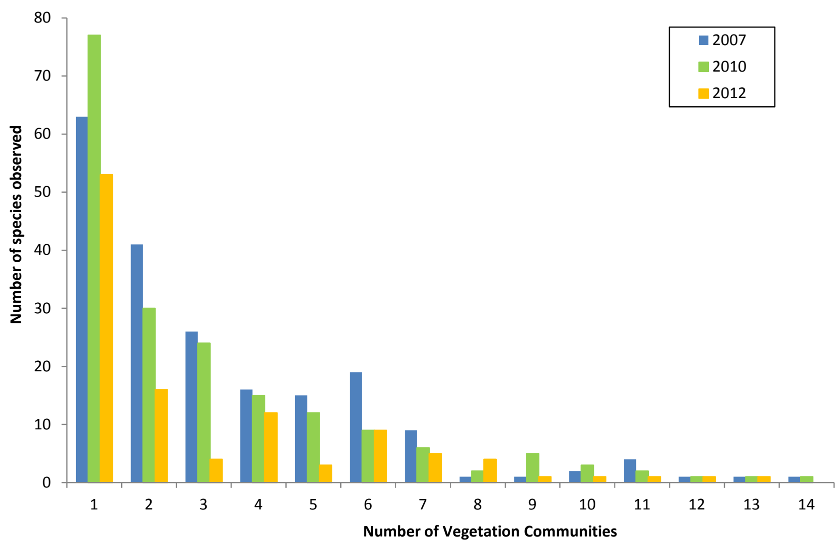


Figure 5-8: **Number of different vegetation communities in which a given species was observed in 2007, 2010, and 2012.** A high proportion of observations were limited to a single community type, whereas only a few species were sampled in eight different communities or more

5.1.5 Species Richness, Diversity, and Evenness of Vegetation Communities

Species richness varied significantly among vegetation communities and across time within some (but not all) communities (Figure 5-9). Overall, the Willow-Sedge wetland (WS) community showed the highest richness relative to the other communities, followed by the Cottonwood-Trifolium (CT) community.The CT community did not have the highest overall species richness (Figure 5-5), but they had the highest richness recorded per transect sampled (Figure 5-10). Commonly Horsetail (CH) had consistently low species richness. Richness per transect was highly variable over time for Marsh Cudweed-Annual Hairgrass (MA), possibly consistent with it being an annual-dommінated, ruderal community; and declined significantly in 2012 for Clover-Oxeye Daisy (CO) and for Bluejoint Reedgrass (BR), possibly reflecting the lower number of transects sampled in 2012. Lack of replicates in one or more years precluded comparing richness across years for certain communities (e.g., WB, BS, WS).

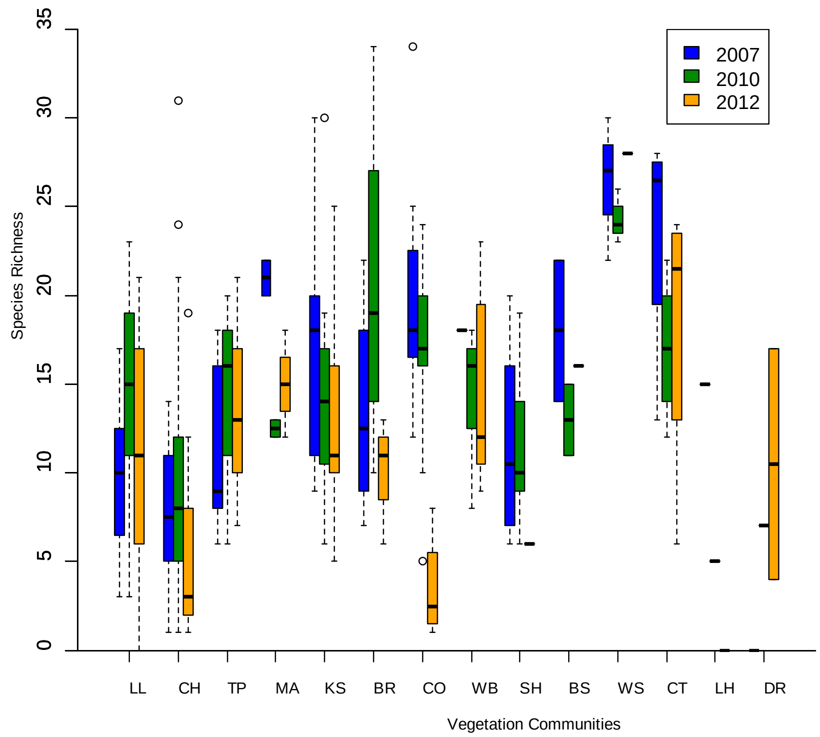


Figure 5-9: Variation in species richness per transect over time, per vegetation community. Vegetation communities were ordered per seral stage, from pioneering to late seral communities. Refer to Table 4-1 for a description of the vegetation communities. The boxes represent 25 per cent and 75 per cent of the ranked data. The horizontal line inside the box is the median. The length of the boxes is their interquartile range. Whiskers are drawn from the top of the box to the largest observation within 1.5 interquartile range of the top, and from the bottom of the box to the smallest observation within 1.5 interquartile range of the bottom of the box. Clear circles are outliers. Differences in species richness were statistically significant among years (F=6.1, p=0.003) and vegetation communities (F=6.8, p=0.00001). Interactions were significant (F=8, p=0.03); one-way ANOVAs found significant differences among vegetation communities in 2007 (F=24.9, p=0.0001), 2010 (F=3.7, p=0.002), and 2012 (F=3.7, p=0.003), and among years only for CO communities (F=15.1, p=0.0002). Differences in richness in WB, BS, WS, LH and DR were not tested because of lack of replicates in one or more years

Differences in species diversity were statistically significant among years and vegetation communities (Figure 5-10). Of the communities for which data were sufficient to allow multi-year comparisons, diversity per transect appeared to increase over time in Lady's thumb-Lamb's quarter (LL) and Toad Rush-Pond Water-starwort (TP), and to decrease over time in Marsh Cudweed-Annual Hairgrass (MA), Clover-Oxeye Daisy (CO), Swamp Horsetails (SH), and Cottonwood-Trifolium (CT). Diversity in the other communities was relatively stable across time (Figure 5-11).

Evenness values were relatively low and not statistically different between years and among communities, suggesting that a few species were dominating each of the communities at the local scale (Figure 5-11).

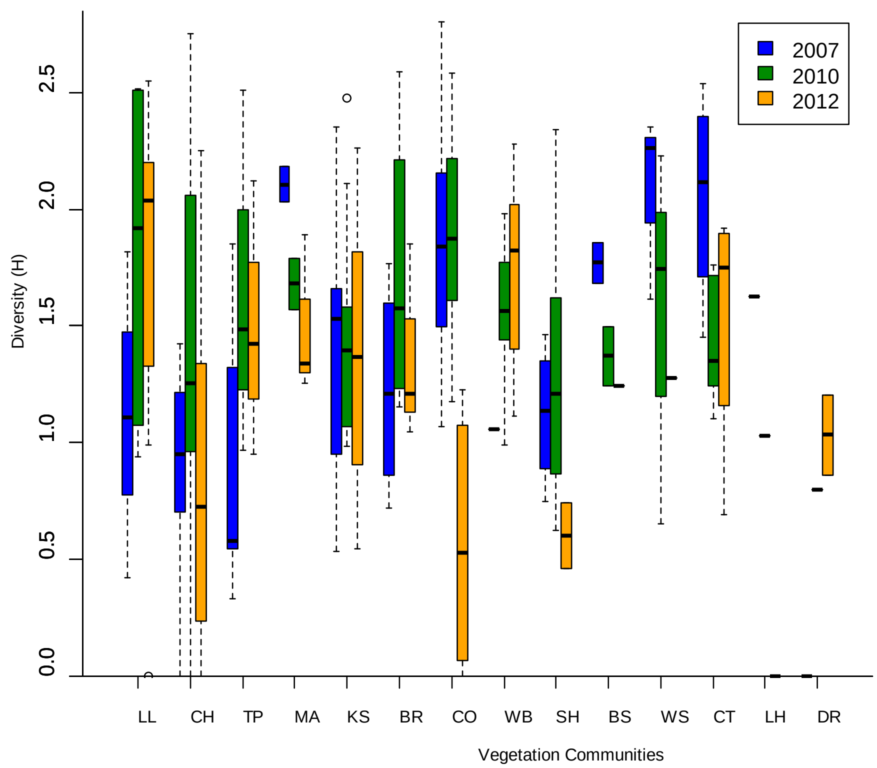


Figure 5-10: Variation in species diversity (Shannon's H) per transect over time, per vegetation community. Vegetation communities were ordered per seral stage, from pioneering to late seral communities. Refer to Table 4-1 for a description of the vegetation communities and refer to Figure 5-10 for box-plot interpretation. Differences in species diversity were statistically significant among years ($F=1.3$, $p=0.02$) and vegetation communities ($F=1.1$, $p=0.002$). Interactions were significant ($F=2$, $p=0.01$); one-way ANOVAs found significant differences among vegetation communities only in 2007 ($F=17.8$, $p=0.0001$), and among years for CO communities ($F=6.2$, $p=0.004$), and LL communities ($F=4.7$, $p=0.02$). Differences in richness in WB, BS, WS, LH and DR were not tested because of lack of replicates in one or more years

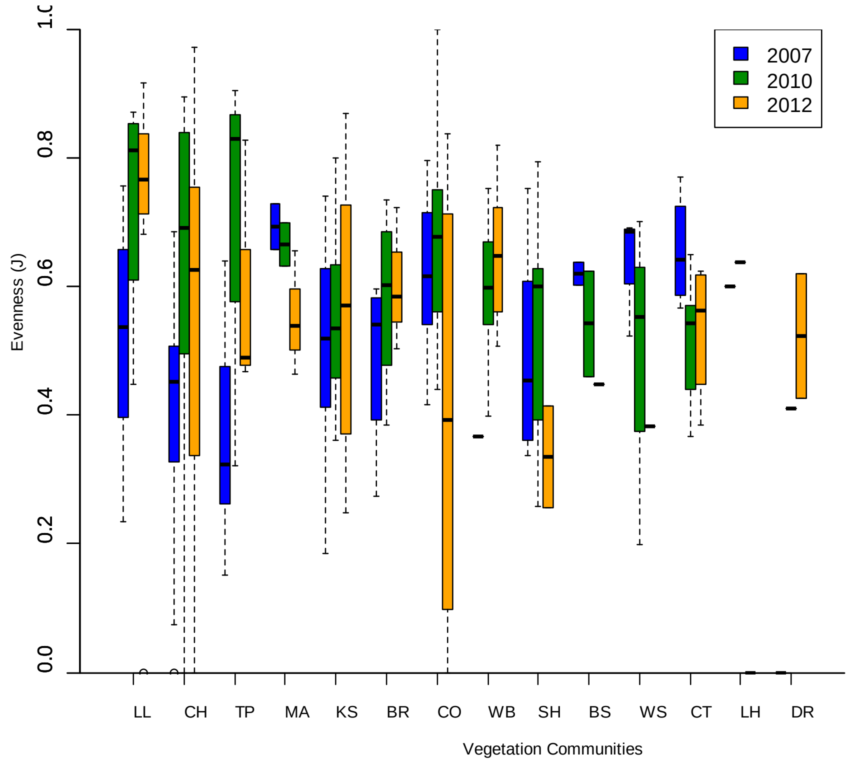


Figure 5-11: Evenness (J) of the distribution of species per transect over time, per vegetation communities. Vegetation communities were ordered per seral stage, from pioneering to late seral communities. Refer to Table 4-1 for a description of the vegetation communities and refer to Figure 5-10 for box-plot interpretation. Differences in evenness were not significant among years or vegetation communities ($p > 0.05$)

5.1.6 Species Richness, Diversity, and Evenness and Landscape Units

The total number of species recorded per landscape unit increased between 2010 and 2012 for most landscape units (Figure 5-12). Exceptions to this were Sullivan Arm, Windfall Creek, Grouse Creek, and Yellow Jacket Creek. In 2010, 22 new species were recorded in Kinbasket Reservoir followed by an additional 42 new species in 2012. It is likely that we will continue to record new species in each landscape unit in future years (Figure 5-2).

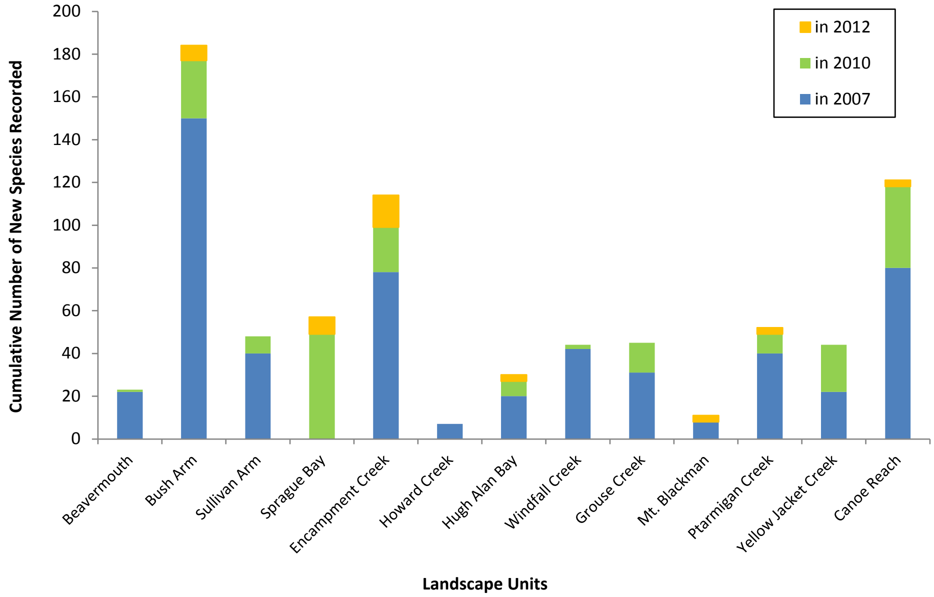


Figure 5-12: Total number of new species recorded in each landscape unit over time. Howard Creek was sampled only in 2007, Sprague Bay and Hugh Alan Bay were not sampled in 2007, and Beavermouth was not sampled in 2012

More species were documented in Bush Arm than in any other landscape unit, although Canoe Reach and Encampment Creek were also relatively speciose (Table 5-4). Although these landscape units were sampled more intensely than the other units, they were also the most diverse (see below). Species richness declined in most landscape units between 2007 and 2012, sometimes quite substantially (e.g., Bush Arm, Sullivan Arm, Yellow Jacket Creek, Canoe Reach). Species richness was similar between 2007 and 2012 in Mt. Blackman and Hugh Alan Bay. The two most northerly landscape units, Yellow Jacket Creek and Canoe Reach, increased in richness between 2007 and 2010 before declining in 2012.

Table 5-4: **Species richness in 2007, 2010 and 2012, and total number of species recorded over time in each landscape unit.** Landscape units are recorded from south to north in Kinbasket Reservoir. '-' indicates decrease; '- -' indicates no sampling in that year or comparison were possible

Landscape Unit	Species Richness			Total[1]	Direction of change
	2007	2010	2012		
Beavermouth	22	7	--	23	-
Bush Arm	150	103	72	184	-
Sullivan Arm	40	35	3	48	-
Sprague Bay	--	49	38	57	-
Encampment Creek	78	72	59	114	-
Howard Creek	7	--	--	7	--
Hugh Alan Bay	20	18	15	30	=
Windfall Creek	42	19	2	44	-
Grouse Creek	31	29	8	45	-
Mt. Blackman	8	2	8	10	=
Ptarmigan Creek	40	27	23	52	-
Yellow Jacket Creek	22	39	2	44	-
Canoe Reach	80	93	35	121	-

[1]Total number of new species recorded from 2007 to 2012

To account for differences in sampling effort, richness was subsequently weighted against the number of transects sampled (Figure 5-13). The richest site overall after standardization was Yellow Jacket Creek (in 2007), while the richest site in 2012 was Sprague Bay. Encampment Creek was the only site to show an increase in richness in 2012 compared to 2012; richness at most sites declined.

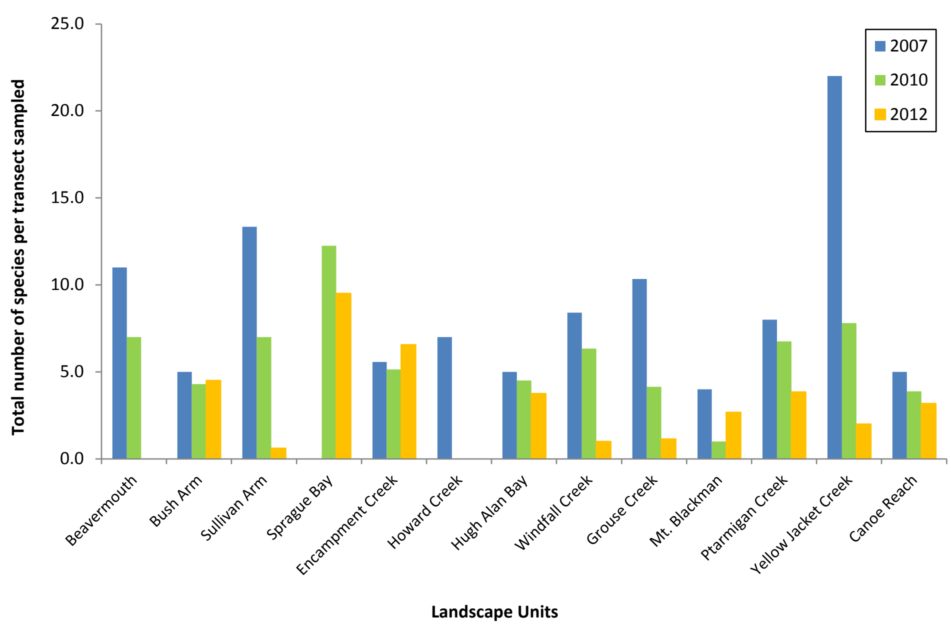


Figure 5-13: **Total species richness per transect, in each landscape unit over time.** Landscape units were ordered from south to north in Kinbasket Reservoir. Beavermouth was not sampled in 2012, Sprague Bay in 2007, and Howard Creek in 2010 and 2012

The differences in richness aver time and across landscape units were statistically significant (Figure 5-14). The relatively low richness of certain landscape units (e.g., Sullivan Arm, Grouse Creek, Hugh Alan Bay, Mt. Blackman) may be due to greater levels of sedimentation observed at these landscape unit over time (see Section 6.0).

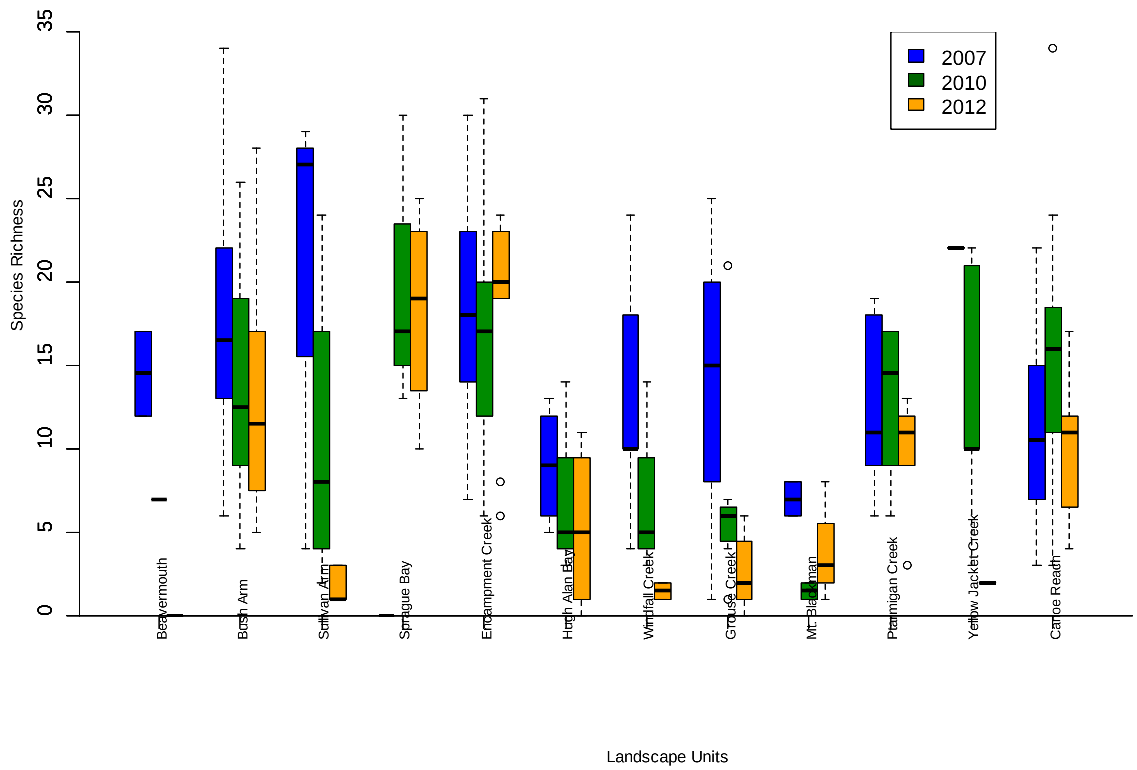


Figure 5-14: Species richness per transect in each landscape unit in 2007, 2010 and 2012. Landscape units are ordered from south to north in the Kinbasket Reservoir. Refer to Figure 5-10 for boxplot interpretation. Differences in species richness were statistically significant among years (F=10.3, p=0.00009), and among landscape units (F=8.3, p=0.00001). Interactions were barely significant (F=1.7, p=0.0503); one-way ANOVAs found significant differences among landscape units in 2007 (F=12, p=0.0001), and among years in Bush Arm (F=6.7, p=0.002), Sullivan Arm (F=9.2, p=0.01), Windfall Creek (F=5.2, p=0.048), and Grouse Creek (F=6.8, p=0.01). Differences in richness in Beavermouth, Sprague Bay, and Yellow Jacket Creek were not tested because of lack of replicates in one or more years

Differences in species diversity among years and landscape units were significant (Figure 5-15). Landscape units known to be prone to sediment deposition and transport (Grouse Creek, Mount B3lackman, Windfall Creek) underwent stronger declines in diversity in between 2007 and 2012 than those landscape units where deposition was not as frequently observed (e.g., Canoe Reach; Figure 5-15). Diversity values at Sullivan Arm also dropped substantively in 2012 (Figure 5-15). Moderate increases in species diversity were associated with Sprague Bay and Encampment Creek, and were accompanied by a similar increase in richness (Figure 5-14).

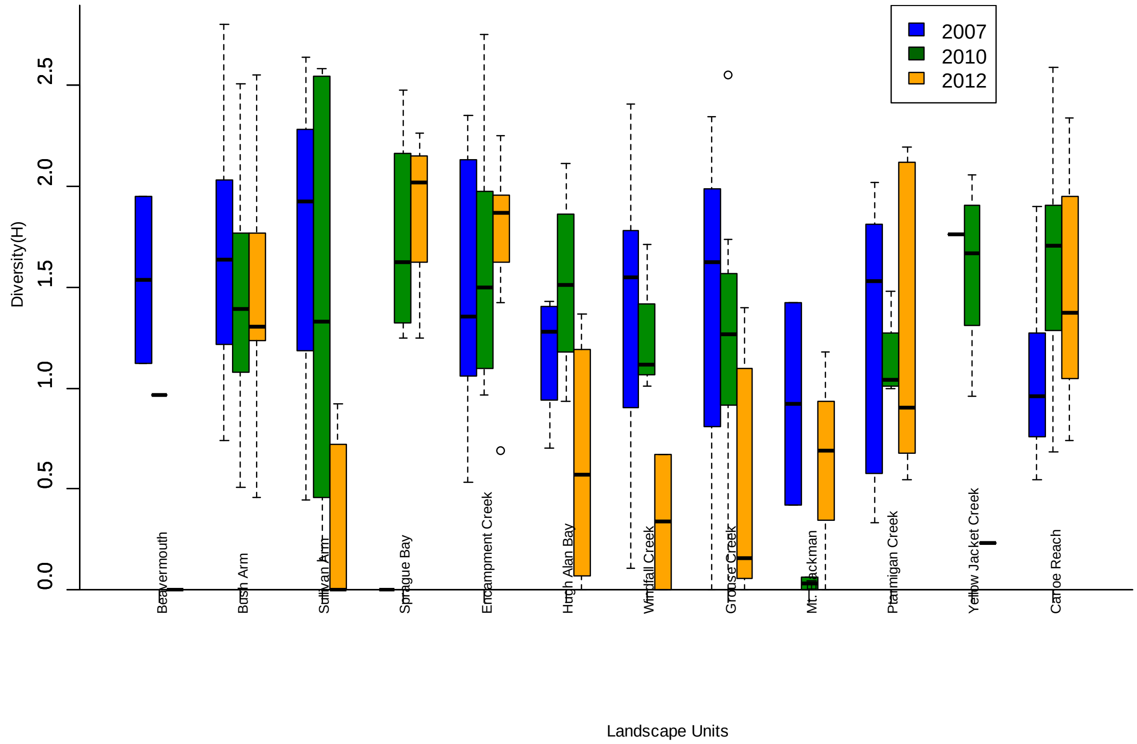


Figure 5-15: Species diversity (Shannon's H) per transect in each landscape unit in 2007, 2010 and 2012. Landscape units are ordered from south to north. Refer to Figure 5-10 for boxplot interpretation. Differences in species diversity were statistically significant among years ($F=5.5$, $p=0.004$), and among landscape units ($F=4.9$, $p=0.00004$). Interactions were also significant ($F=2.4$, $p=0.002$); one-way ANOVAs found significant differences among landscape units in 2007 only ($F=12.5$, $p=0.0001$), and among years in Canoe Reach ($F=7.8$, $p=0.002$). Differences in diversity in Beavermouth, Sprague Bay, and Yellow Jacket Creek were not tested because of lack of replicates in one or more years

Individual landscape units had generally quite variable evenness, both within years (indicated by the long interquartile ranges) and, in certain cases, among years (e.g., Hugh Alan Bay, Mt. Blackman, Canoe Reach). Note that communities were pooled within landscape units for this analysis, which likely accounts for some of the within-region variability. There were also significant differences in evenness values among landscape units (Figure 5-16). As for diversity, there were indications of increased evenness in 2012 in Sprague Bay and Encampment Creek, although the among-year differences were not significant. With the possible exception of Encampment Creek and Canoe Reach, there was no strong indication of a consistent trend toward increased (or decreased) evenness over time, implying that recent reservoir operations have not had a strong directional impact on local community structuring when viewed at the landscape scale.

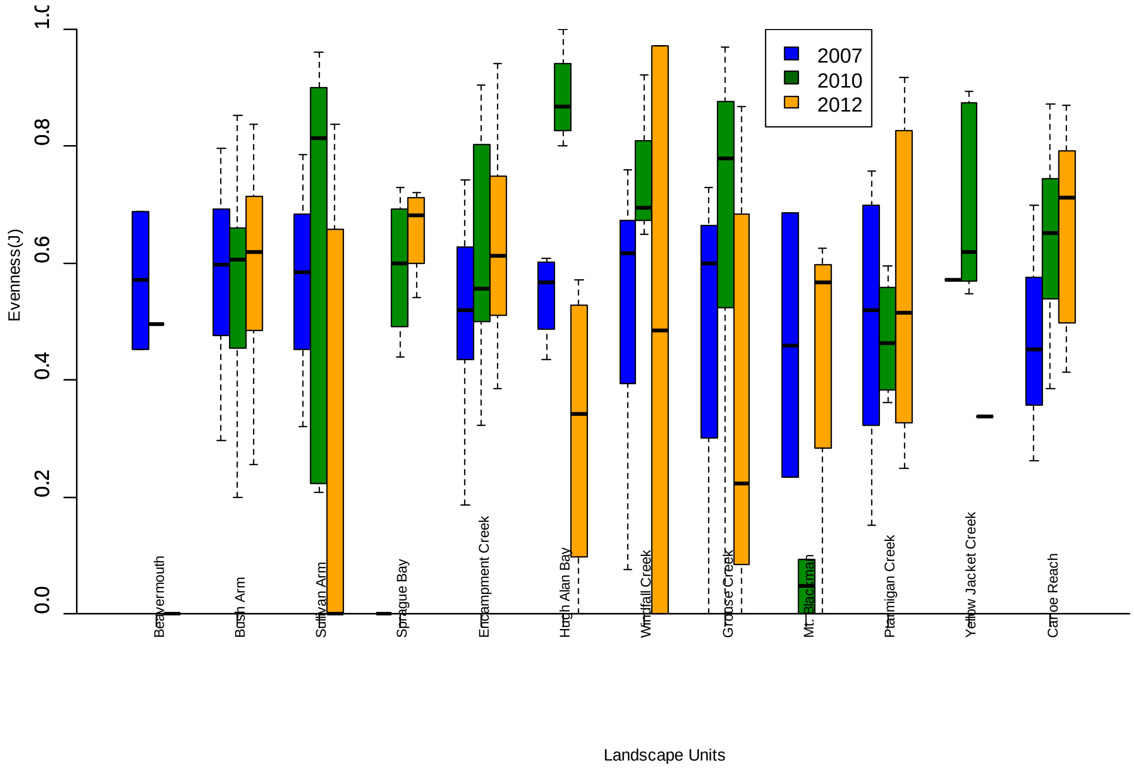


Figure 5-16: Evenness in species' distribution (J) per transect in each landscape unit in 2007, 2010 and 2012. Landscape units are ordered from south to north. Refer to Figure 5-10 for boxplot interpretation. Differences in species evenness were not statistically significant among years ($p > 0.05$), but were among landscape units ($F=2.1$, $p=0.036$). Interactions were also significant ($F=2.5$, $p=0.002$); one-way ANOVAs found significant differences among landscape units in 2007 ($F=6.1$, $p=0.0001$), and among years in Canoe Reach ($F=14.6$, $p=0.0001$). Differences in evenness in Beavermouth, Sprague Bay, and Yellow Jacket Creek were not tested because of lack of replicates in one or more years

5.1.7 Species Richness, Diversity, and Evenness and Elevation

The distribution of vegetation communities among elevation bands in the drawdown zone of Kinbasket Reservoir in 2007, 2010, and 2012 is shown in Figure 5-17. As previously reported (Hawkes *et al.* 2007, 2010), vegetation communities occur occur across an elevational gradient and these gradients are fairly consistent between years. Late seral communities tended to occur at higher elevations, especially Willow-Sedge Wetland (WS) and Cottonwood-Trifolium (CT) communities. The two mid-seral communities, Bluejoint Reedgrass (BR) and Clover-Oxeye Daisy (CO), also tended to be restricted to high elevations. The elvations at which the mid-seral communities occurred increased in a consistent manner from the Toad-Rush Pond Water-Starwort (TP) community to the Bluejoint-Reedgrass community (BR; Figure 5-17).

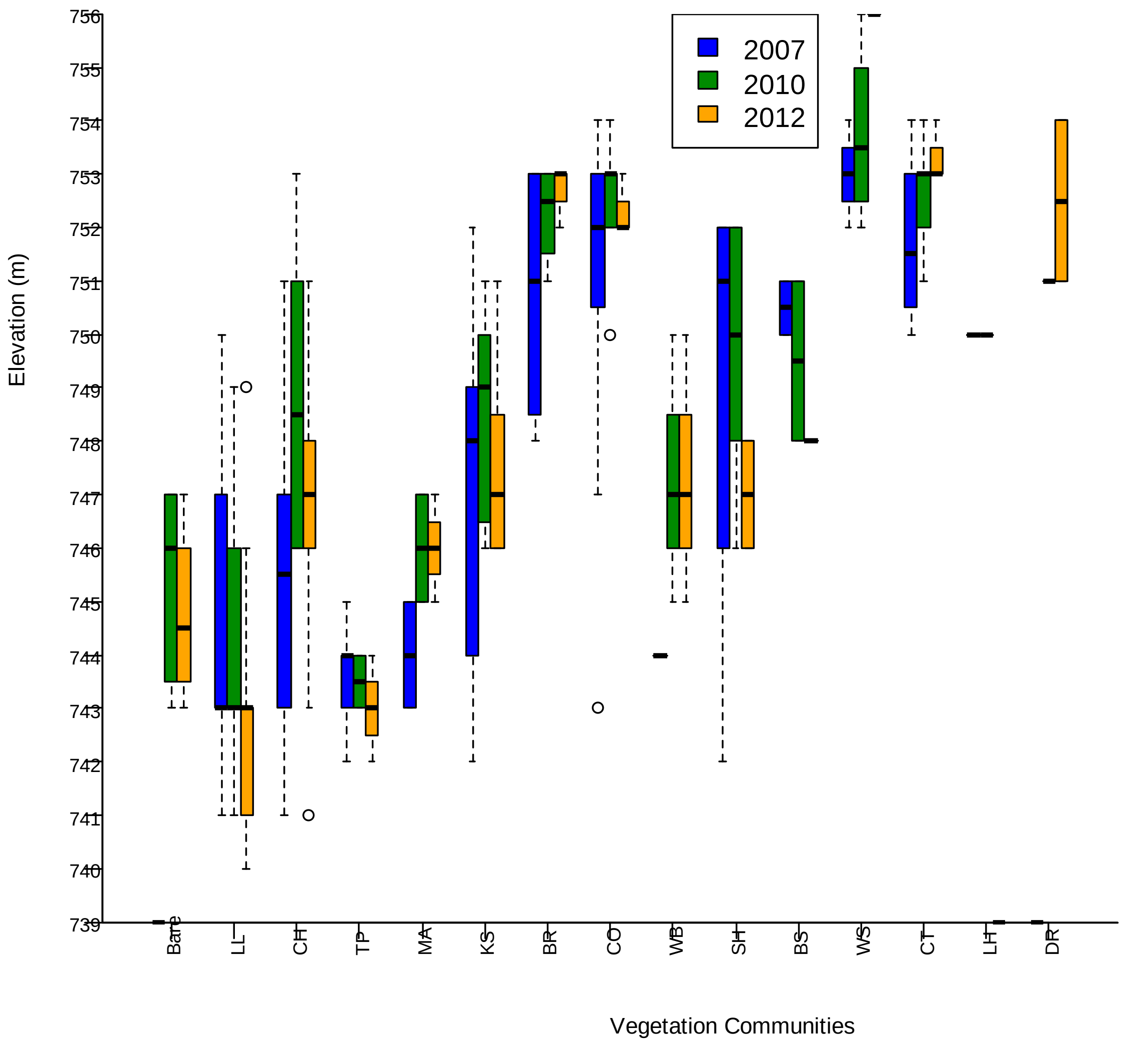


Figure 5-17: Elevational gradient associated with each of the vegetation communities characterized in the drawdown zone of Kinbasket Reservoir in 2007, 2010, and 2012. Vegetation communities are ordered per seral stage, from pioneering to late seral communities. Refer to Table 4-1 for a description of the vegetation communities and refer to 10 for box-plot interpretation

Species richness per transect varied significantly with elevation (Figure 5-18). Richness appeared to increase with elevation particularly in the upper elevation bands. From 750 m ASL to 754 m ASL, there was an apparent decrease in species richness between 2007 and 2012, which in specific cases, may be related to lingering effects of the 2007 high water event (Figure 4-1, Section 6.0) on communities such as the Willow-Sedge Wetland community (WS) found at this elevation (Figure 5-17). The subsequent die-off of species with low tolerance to inundation has likely contributed to the reduction in species richness at elevations near the normal operational maximum of Kinbasket Reservoir (Section 6.0). There also seems to be an decrease in species richness over time at lower elevations, between 743 m ASL and 747 m ASL, possibly associated with the heavy sediment loads observed in 2008 following the 2007 inundation. Alternatively, this decrease could be associated with the higher overall reservoir levels (and longer inundation periods) experienced over the last several years compared to those experienced between 2000 and 2005.

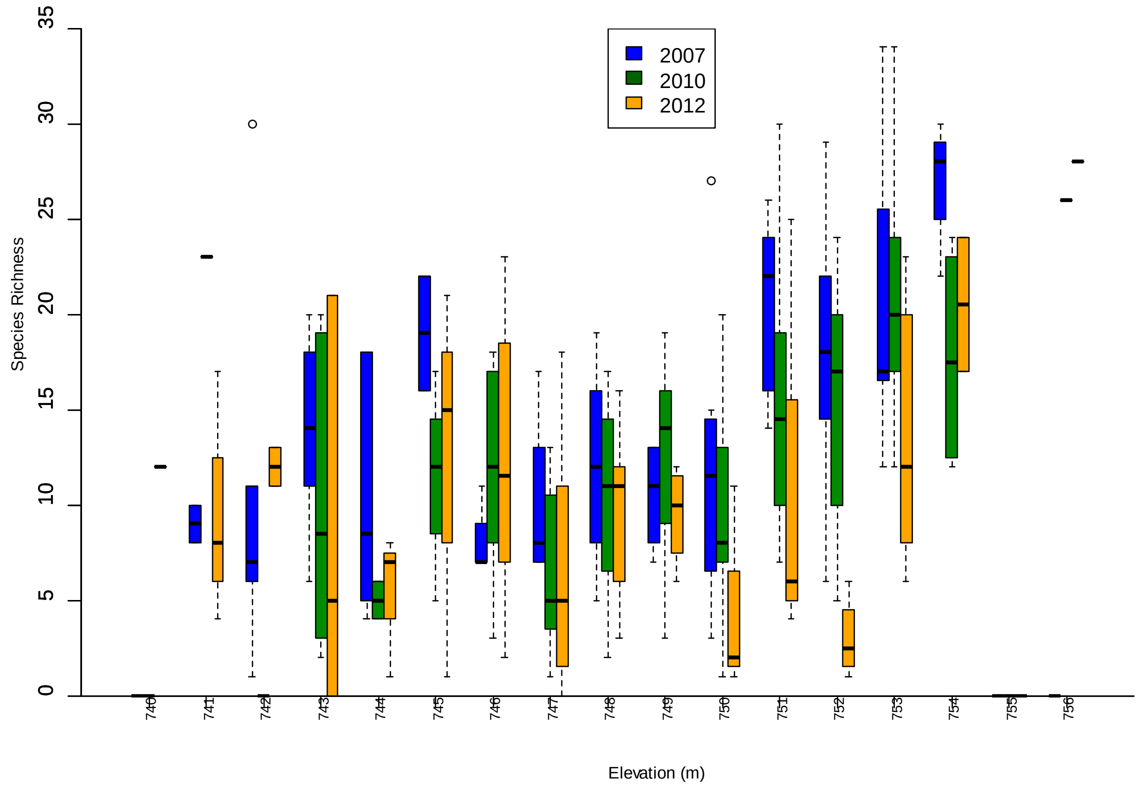


Figure 5-18: Species richness of vegetation per transect in relation to elevation, over time. Refer to Figure 5-9 for boxplot interpretation. Differences in species richness were statistically significant among elevation bands (F=7.5, p=0.00001), and among years (F=9.3, p=0.0001). Interactions were not significant ($p > 0.05$); only elevations from 743 to 754m ASL were tested

In contrast to richness, neither diversity nor evenness of vegetation exhibited strong directional patterns in relation to elevation (Figure 5-19 and Figure 5-20), although diversity did vary significantly across elevation bands and appeared to increase slightly with elevation. Significant differences in eveness were associated with year, but not elevation (Figure 5-20). As with richness, there were notable decreases over time in both diversity and evenness within the upper, 750 m ASL to 754 m ASL bands, continuing the trend observed in 2010. Decreases in these metrics also occurred (at least relative to 2010) within the 744-745 m ASL elevation bands. Evenness appears to be increasing over time within the mid-elevation, 749 m ASL elevation band, although this pattern is not repeated for either richness or diversity.

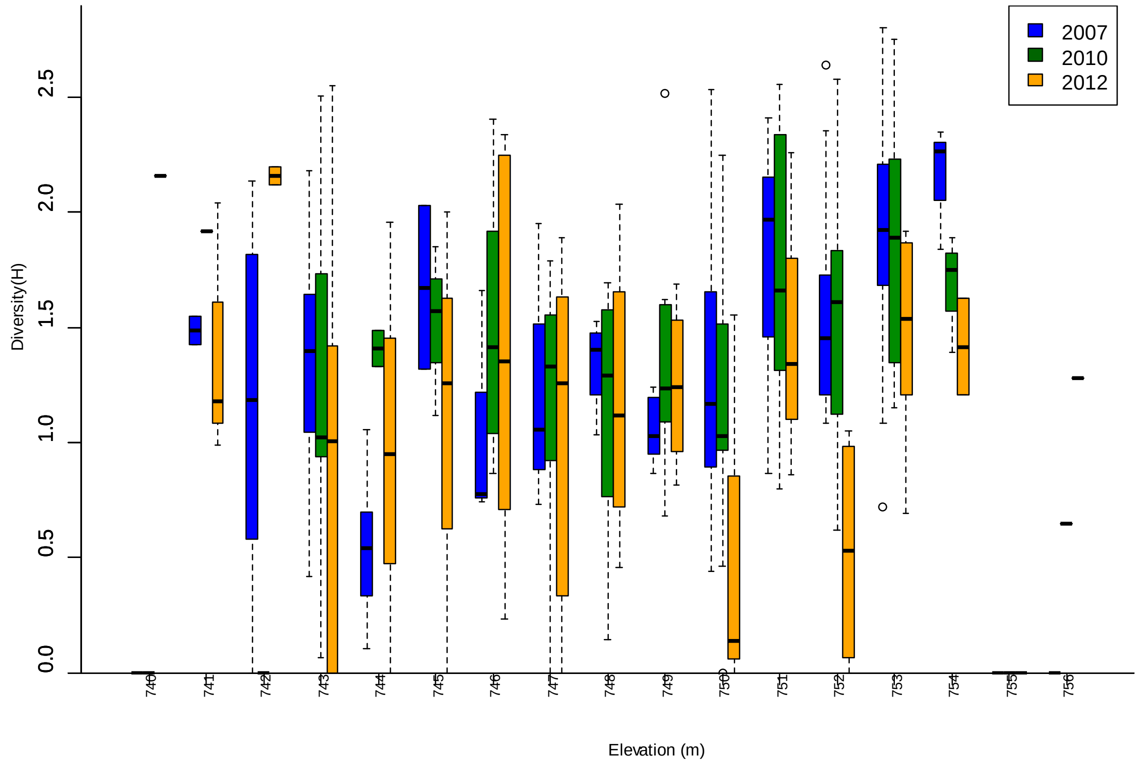


Figure 5-19: Species diversity (Shannon's H) per transect in relation to elevation, over time. Refer to Figure 5-9 for boxplot interpretation. Differences in species diversity were statistically significant among elevation bands (F=3.6, p=0.0001), and among years (F=4.6, p=0.01). Interactions were not significant; only elevations from 743 to 754m ASL were tested

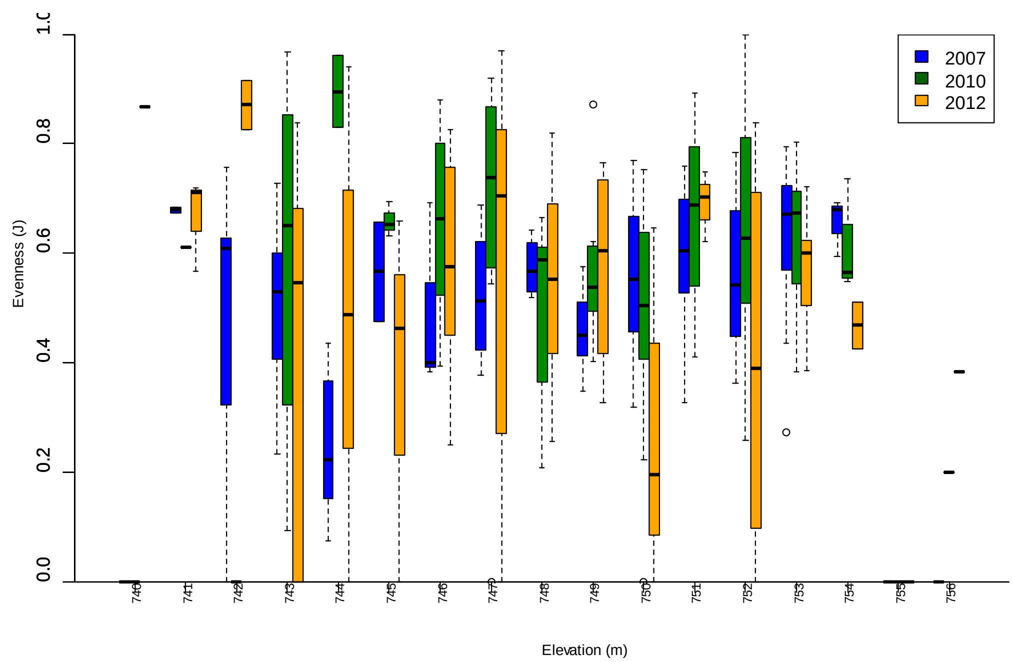


Figure 5-20: Evenness of species' distribution (J) per transect in relation to elevation, over time. Refer to Figure 5-9 for boxplot interpretation. Differences in species evenness were not statistically significant among elevation bands (p>0.05), but

were among years (F=6.4, p=0.002). Interactions were not significant; only elevations from 743 to 754m ASL were tested

5.1.8 Vegetation and Environmental Variables

All variables used in the canonical analyses associated with vegetation varied substantially across all transects sampled (Table 5-5), which was expected given the elevations across which all transects were sampled (i.e., 740–756 m ASL). Shrub and herb cover, as well as organic live matter and mineral soils per cent cover, increased slightly compared to2010 (Hawkes *et al.* 2010). Some of the slopes sampled in 2012 were steeper, while per cent cover of moss and dead organic matter declined relative to 2010.

Table 5-5: Variation in environmental variables across the 68 transects sampled in 2012. All variables were included in the RDA

Variable	Unit	Mean	S.D.	Min	Max
Elevation	m (ASL)	747	4	740	756
Shrub	per cent	2	9	0	69
Herb	per cent	18	22	0	83
Moss	per cent	5	13	0	73
Live Organic Matter	per cent	19	25	0	97
Dead Organic Matter	per cent	14	17	0	85
Decayed Wood	per cent	6	11	0	84
Rock	per cent	12	21	0	94
Mineral Soil	per cent	41	34	0	98
Slope	Degrees	5	6	1	40
Aspect	Degrees	164	97	0	315
Heatload	--	1.0	0.4	0.50	1.50

Three main groups of vegetation were defined in relation to the environmental variables in Table 5-5, as assessed by the RDA (Figure 5-21). Environmental variables included in the analysis after forward selection were transect elevation, heat load, and per cent cover of herbs, moss, rock, live organic matter, and dead organic matter. The first group of species (mainly pioneering and weedy species) was formed of Common Horsetail (EQUIARV) and White Clover (TRIFREP) and was positively associated with a high cover of rock. The second group of vegetation was comprised of wetland-associates including Swamp Horsetail (EQUIFLU), Small-flowered Bullrush (SCIRMIC), Purple-leaved Willowherb (EPILCIL), and Small Bedstraw (GALITRD), and was associated with high herbaceous cover, high elevations, and high ground cover of organic live and dead matter. A third species cluster appeared to be concentrated at lower elevations but was not closely correlated with any of the other environmental variables analyzed; this group was comprised largely of weedy and/or ruderal species such as Common Knotweed, Lady's Thumb, and Marsh Cudweed (Figure 5-21).

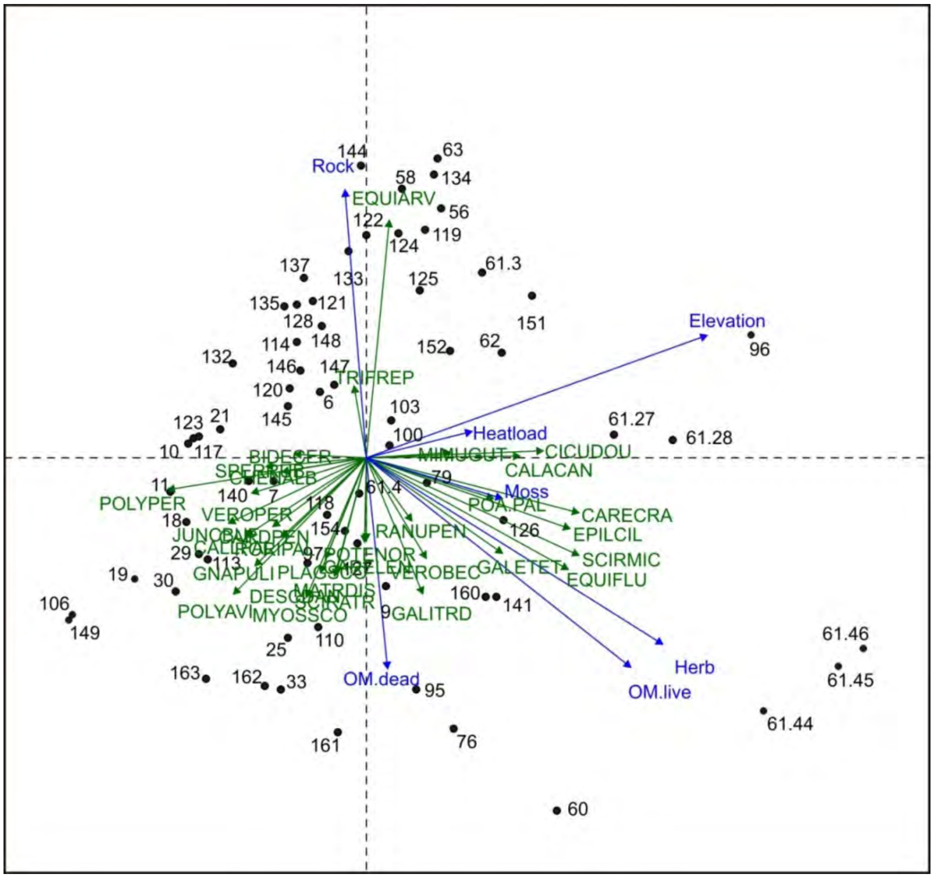


Figure 5-21: Redundancy analysis diagram showing relationships between the cover of 32 main species per transects, and a selection of environmental variables in Kinbasket Reservoir (adj-R^2=0.19, p=0.00001). Axis X shows 10.3 per cent and axis Y, 6.3 per cent of the variation associated with the per cent cover of vegetation species. Vectors in green represent the species; vectors in blue represent environmental variables. Angles between vectors are inversely proportional to strength of correlation. The fitted Z-scores were plotted

A second RDA summarized data for each vegetation community and, as a complement to the PCA presented earlier (Figure 5-4), assessed whether the vegetation communities were associated with specific species and environmental conditions (Figure 5-22). Results suggest that, in general, communities were not clearly differentiated by the environmental variables included in the analysis after forward selection (the two included variables were elevation and herb cover). The Bluejoint Reedgrass (BR) and Willow-Sedge Wetland (WS) communities appeared to be associated with high herb cover although, unexpectedly, BR was not associated with its namesake species (CALACAN) and WS was not associated with any willow species. The Cottonwood-Trifolium (CT) community, as expected, was associated with higher elevations, but was not associated in ordination space with its namesake species (POPUTRI) or with deciduous shrubs. The Common Horsetail (CH) community was not associated with any environmental variable but, as expected, was associated with species such as Common Horsetail (EQUIARV), Clover (TRIFREP), and Lamb's-quarters (CHENALB). Some communities such as WS, CH, and Clover-Oxeye Daisy (CO) were well separated in ordination space from other communities, suggesting they are relatively distinct ecologically, while a number of communities (e.g., KS, SH, MA, BS) were clustered fairly closely in ordination space, suggesting the ecological distances among them are small.

The moderate relationships between vegetation communities, vegetation species, and environmental variables reflect results presented earlier: Figure 5-22 successfully relates some, though not all, of the communities delineated in the drawdown zone to the main species associated with those communities. Likewise Figure 5-21 confirms some, but not all, of these relationships.

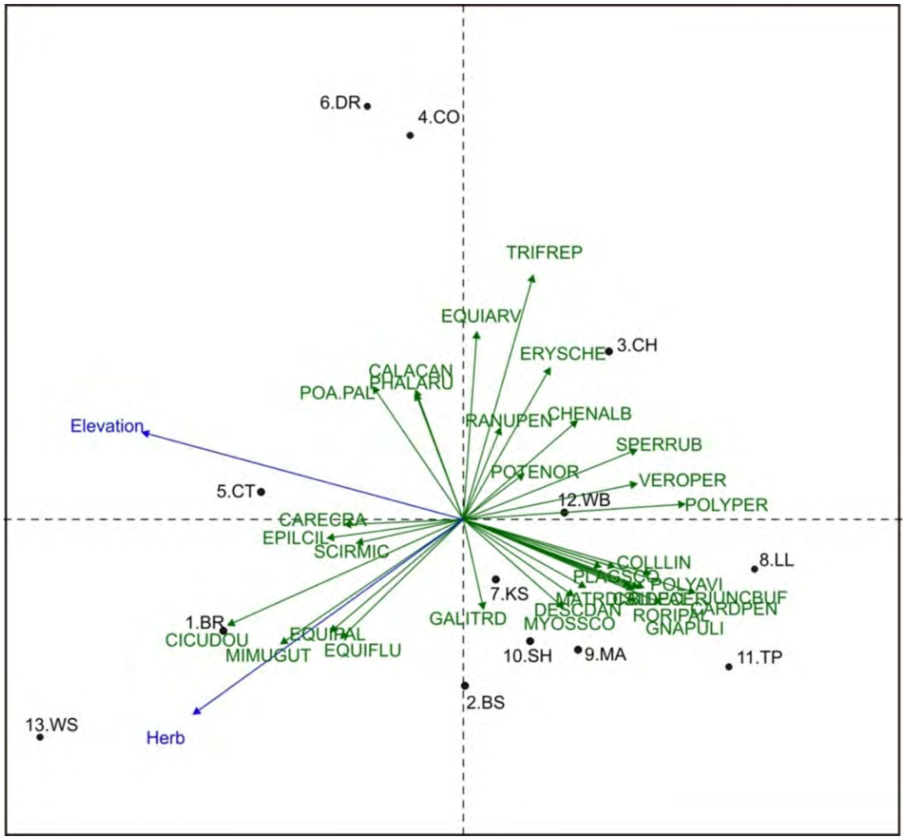


Figure 5-22: Redundancy analysis diagram showing relationships between the cover of 32 main species per transects, and a selection of environmental variables in Kinbasket Reservoir (adj-R2=0.22, p=0.00007). Axis X shows 23.6 per cent and axis Y, 11.5 per cent of the variation in cover of the species. Vectors in green represent the species; vectors in blue represent the environmental variables. Angles between vectors are inversely proportional to strength of correlation. The projection of the vegetation communities (black dots, refer Table 4-1 for description of acronyms) at right angle on the vectors of response quantitative variables reflects their correlations. The fitted Z-scores were plotted

5.2 Vegetation Data – Polygons

5.2.1 Spatial Extent of Vegetation Communities

The total spatial extent of vegetation cover by landscape unit was assessed using 2007 as the baseline for most landscape units; 2008 was used for Succour Creek and Sprague Bay. In general, the spatial extent of vegetation communities delineated in the drawdown zone has not changed substantially over time (Table 5-6). Where small changes are noted (e.g., Beavermouth, Sullivan Arm), the changes can be attributed to mapping errors. We considered a change of at least

10 per cent to be indicative of a change, primarily because this was the level of change that we could detect in our GIS[5]. Changes less than four hectares were considered to be associated with mapping error. Although the total spatial extent of vegetation was not significantly different between 2007 and 2010 (using landscape units as replicates; F=0.06, p=0.704), the difference between 2007 and 2012 was significant (F=8.6, p=0.0002). The spatial extent of vegetated areas in 2012 is virtually unchanged from 2010.

The differences observed between 2007 & 2008 and both 2010 & 2012 (which was the same, but higher than 2007 or 2008) can be attributed to increased precision in mapping in 2010, which is directly related to the increased quality of the aerial imagery over previous years. Furthermore, the accumulation of three years of field experience in the drawdown zone of Kinbasket Reservoir enabled us to map vegetated areas that may have previously been overlooked. Examples of where this occurred include the mouth of Bush Arm, specific areas within Encampment Creek, and a portion of Canoe Reach.

Table 5-6: Total spatial extent of vegetation (hectares) in 2007, 2010, and 2012 from aerial photography. Landscape units are ordered from south to north in Kinbasket Reservoir. '--' indicates no comparison possible; '=' indicates no or very minor change; and '+' indicates an increase. Differences were statistically significant among landscape units (F=8.6, p=0.0002; Sprague Bay and Succour Creek not tested because of lack of replicates in 2007), but not among years.

Landscape Unit	2007	2008[1]	2010	2012	Change from 2007[2]	Direction of Change[3]
Beavermouth	23.13	25.17	26.31	26.27	3.14	+
Bush Arm	896.43	441.56	1021.86	1021.23	124.8	+
Succour Creek	--	86.41	121.36	121.46	35.05	+
Sullivan Arm	1.25	1.37	1.85	1.82	0.57	+
Sprague Bay	--	54.59	33.41	33.4	-21.19	-
Encampment Creek	57.03	52.65	68.39	68.51	11.48	+
Howard Creek	7.39	4.8	11.64	11.63	4.24	+
Hugh Alan Bay	35.81	28.34	37.33	36.98	1.17	=
Windfall Creek	10.54	11.09	12.38	12.89	2.35	+
Grouse Creek	12.72	9.29	12.76	12.91	0.19	=
Mount Blackman	4.04	2.17	4.15	4.22	0.18	=
Ptarmigan Creek	15.73	12.19	15.79	15.88	0.15	=
Yellow Jacket Creek	31.14	23.44	31.81	31.81	0.67	=
Canoe Reach	683.17	374.78	770.64	771.78	88.61	+
Total Area Mapped	**1778.38**	**1127.85**	**2169.71**	**2170.79**	**251.41**	**+**

[1] The extent of mapping in 2008 is a reflection of the timing of aerial photo acquisition (see Figure 4 1).
[2] Change computed from 2008 when no sampling occurred in that landscape unit in 2007
[3] The change represents at least a 10 per cent increase or decrease to be classified as positive or negative

Of the 19 communities mapped between 2007 and 2012, the total area increased for nine communities (BR, CH, DR, LL, MA, RC, TP, WB, and MC), decreased for six communities (CO, CT, LH, KS, SH, WD), and remained unchanged for four (BS,

[5] A change of 10 percent is equivalent to ~ 4 ha.

FO, KS, and WS). The RD community did not change in extent between 2010 and 2012 (Table 5-7). Total spatial extent was significantly different among vegetation communities (F=5.2, p=0.003), and among years (F=7.9, p=0.009). Interactions were not significant.

Although 2007 is currently considered the baseline year, differences between 2010 and 2012 were also assessed, mainly to evaluate the precision of the photography and to determine if any changes had occurred between 2010 and 2012. The spatial extent of 15 of the 19 communities changed by < 10 per cent between 2010 and 2012. The extent of two communities (RC and BS) decreased by ~11 per cent, the MC community decreased by ~14 percent while the WD and DR communities increased by ~13 and ~30 per cent, respectively. These within community changes do not affect the overall spatial extent of mapped communities in the drawdown zone of Kinbasket Reservoir; however, the increase in the WD and DR communities is notable and likely related to the lack of woody debris control (i.e., burning) since 2007.The decrease in the FO community observed is related to the extent of mapping of that community, which occurs above the normal operating maximum of Kinbasket Reservoir.

Table 5-7: Total spatial extent of vegetation communities (VCC; hectares) mapped in 2007, 2010, and 2012. Landscape units are ordered from south to north in Kinbasket Reservoir. 'N/A indicates no comparison possible; '=' indicates no or very minor change; and '+' indicates increase. Refer to Table 4-1 for plant community codes. Differences between 2010 and 2012 for each vegetation community individually are presented in the last column of the table

	Year				Change	Direction of	Significance of	2010 vs.
VCC	**2007**	**2008[1]**	**2010**	**2012**	**from 2007**	**Change**	**Change**	**2012**
LL	463.5	116.98	719.08	713.09	249.59	+	n.s	-0.8%
CH	177.12	195.1	279.63	281.34	104.22	+	F=6.3, p=0.009	0.6%
TP	88.99	28.23	266.87	265.03	176.04	+	n.s	-0.7%
MA	106.06	51.56	110.2	110.44	4.38	=	N/A	0.2%
KS	216.1	238.59	210.17	215.57	-0.53	=	F=10.8, p=0.01	2.6%
BR	16.73	18.1	41.5	40.68	23.95	+	n.s	-2.0%
RC	9.37	20.94	31.47	27.98	18.61	+	N/A	-11.1%
RD	N/A	N/A	0.59	0.59	0	=	N/A	0.0%
CO	146.02	116.7	135.67	125.26	-20.76	-	F=10.95, p=0.0005	-7.7%
WB	4.46	15.46	128.85	129.71	125.25	+	n.s	0.7%
SH	145.84	105.48	52.41	55.03	-90.81	-	n.s	5.0%
BS	9.28	8.23	12.02	10.69	1.41	+	N/A	-11.1%
WS	35.7	25.9	34.47	32.39	-3.31	-	F=10.8, p=0.01	-6.0%
CT	41.37	38.67	20.24	18.65	-22.72	-	F=4.4, p=0.01	-7.9%
LH	3.53	1	0.52	0.52	-3.01	-	N/A	0.0%
MC	18.33	11.2	0.22	0.19	-18.14	-	N/A	-13.6%
DR	25.92	43.39	36.83	47.86	21.94	+	F=5.8, p=0.01	29.9%
FO	15.85	12.98	18.99	16.56	0.71	=	F=6.15, p=0.01	-12.8%
WD	254.19	79.34	69.99	79.21	-174.98	-	N/A	13.2%
Total	**1778.36**	**1127.85**	**2169.72**	**2170.79**	**496.44**			

[1]The extent of mapping in 2008 is a reflection of the timing of aerial photo acquisition (see Figure 4-1).

The distribution of vegetation communities by landscape unit and year is shown in Figure 5-23. The relative spatial extent of each community is shown to provide a sense of how the spatial distribution of each community contributed to total vegetation cover each year. For example, six communities were mapped for Beavermouth (BM) in 2007 with the CO community covering the greatest area. In 2010, only three communities were mapped for BM, with the CH covering the largest area. A similar pattern was observed in 2012 and is a function of improvements associated with the mapping methodology and not due to the communities being absent or overlooked. Canoe Reach (CR) and Bush Arm (BA) continue to be the most diverse landscape units with 13 and 15 vegetation communities, respectively, in agreement with the greater spatial extent of mapped vegetation communities within these units (Table 5-6). The CO, CH, and KS communities continue to be the most widespread, occurring at between 10 and 13 landscape units in each year. The number of landscape units at which driftwood (DR) was mapped increased to 12 in 2012 (2007: n = 7; 2010 n = 10). The distribution and spatial extent of vegetation communities within each landscape unit was relatively unchanged between 2010 and 2012.

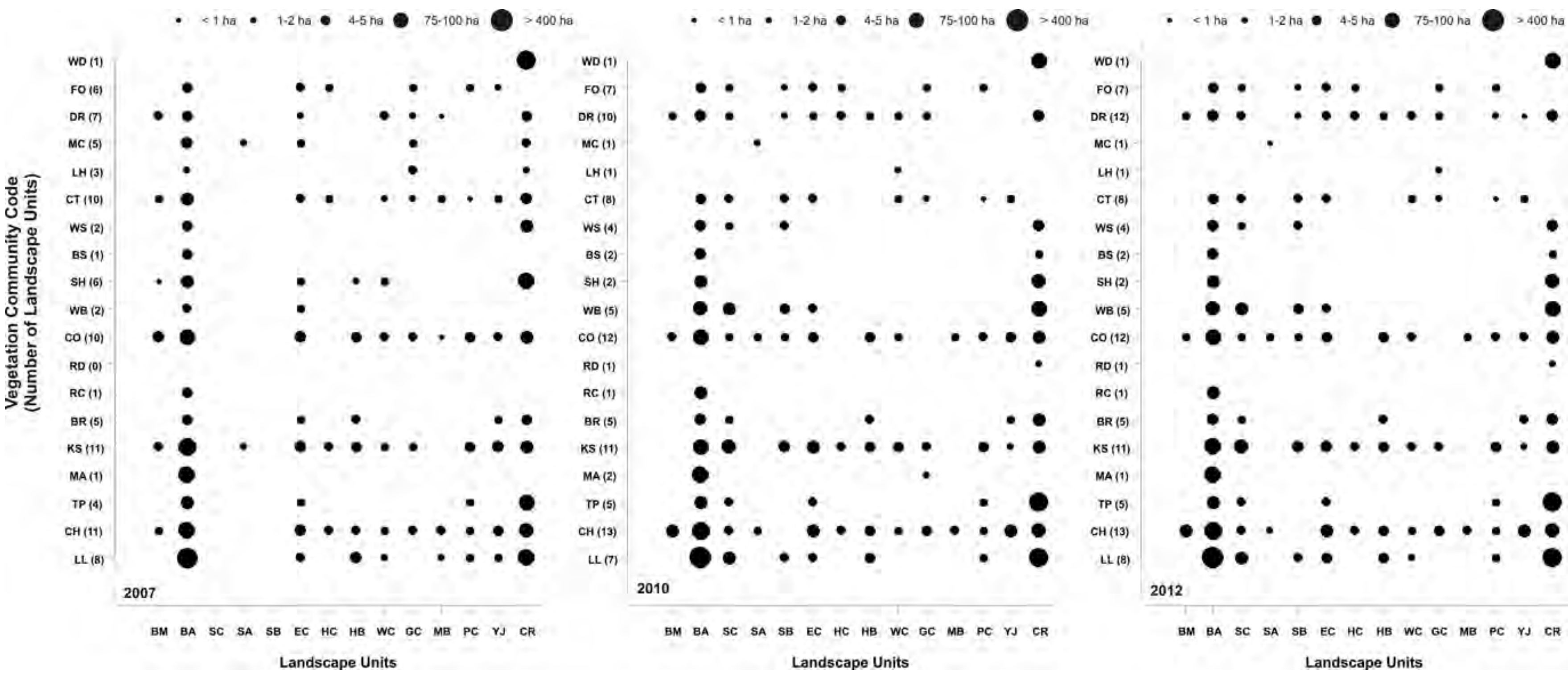


Figure 5-23: The relative distribution of each vegetation community by year and landscape unit. Vegetation community codes are defined in Table 4-1. The size of the points is proportional to the communities' spatial extent in the landscape unit. The number in brackets after the vegetation community codes refers to the total number of landscape units in which that community occurs. Landscape units are ordered south to north: BM – Beavermouth; BA: Bush Arm; SC = Succour Creek; SA = Sullivan Arm; SB = Sprague Bay; EC = Encampment Creek; HC = Howard Creek; HB = Hugh Alan Bay; WC = Windfall Creek; GC = Grouse Creek; MB = Mount Blackman; PC = Ptarmigan Creek; YC = Yellow Jacket Creek; CR = Canoe Reach

The spatial extent and number of vegetation communities mapped per elevation band has changed since 2007 (Figure 5-24). This is mainly related to improvements associated with the accuracy and precision of vegetation polygon delineation realized in 2010. The approach used in 2010 was carried forward into 2012, which is why the total spatial extent and number of communities per elevation band vary only slightly between those two years. The total spatial extent and number of communities mapped per elevation band in 2008 was limited by the late date of photo acquisition, but it is notable that in all years, the number of communities mapped per elevation band generally increases with increasing elevation and an asymptote is reached in the 749 to 750 m ASL range.

The spatial extent of vegetation is greatest in the 743 to 744 m ASL band in 2007, 2010, and 2012, but only slightly. The cover of vegetation is similar for elevations ranging from 741 to 752 m ASL, dropping as elevation increases to 755 m ASL, which is likely related to the topography associated with these elevations, which tends to be steep.

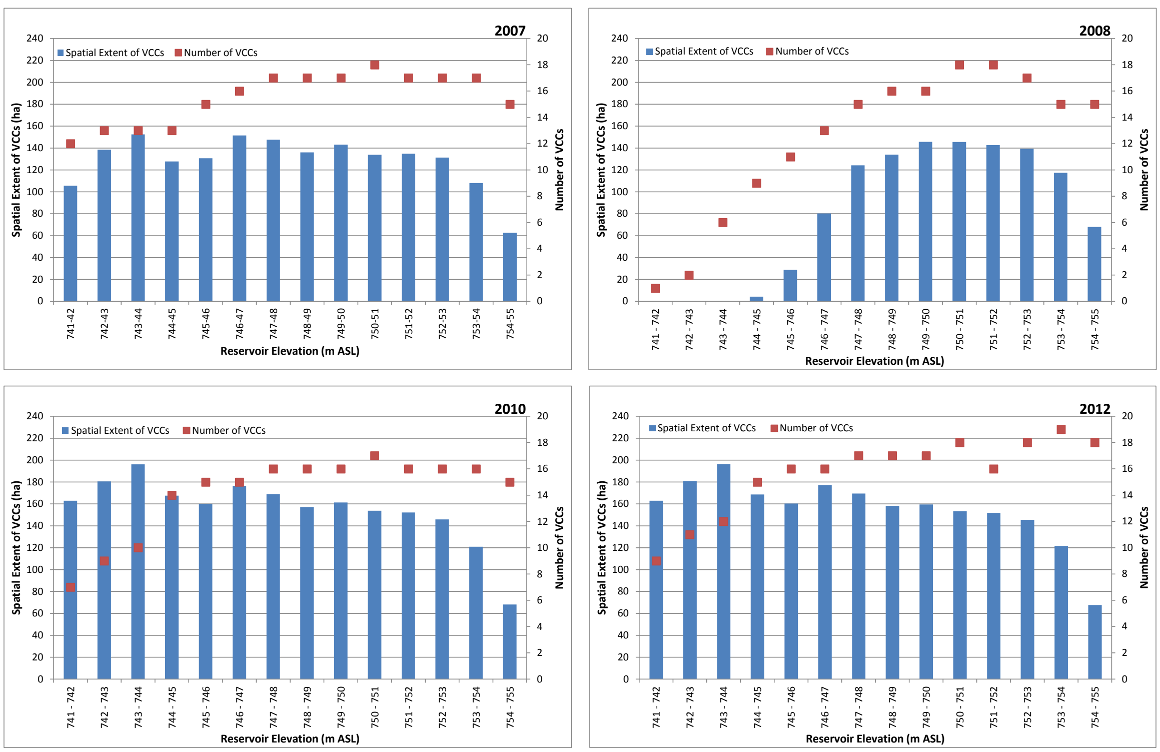


Figure 5-24: Total spatial extent and number of vegetation communities per elevation band and year of sampling

5.2.2 Vegetation Communities and Landscape Unit

The distribution and number of vegetation communities mapped for each landscape unit in 2012 was similar to 2010; both years varied relative to 2007 (Figure 5-23 and Figure 5-25). There were two changes in 2012 compared to 2010, both of which were associated with landscape units in the north end of the reservoir (Ptarmigan Creek and Yellow jacket Creek). The number of vegetation communities increased at Ptarmigan and Yellow Jacket Creek and these increases were associated with the addition of driftwood (DR) to the landscape units.

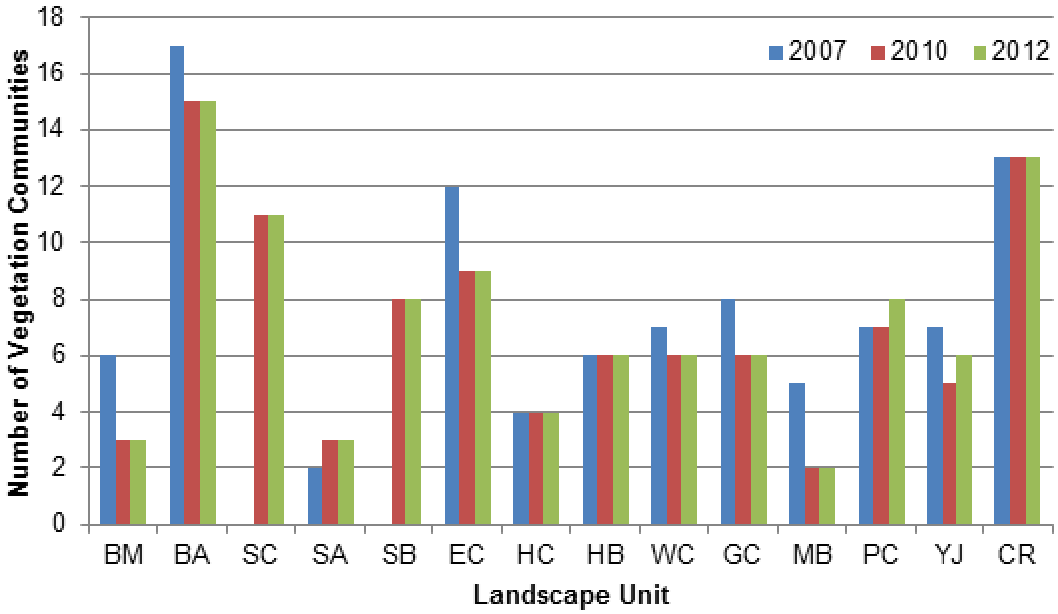


Figure 5-25: Number of vegetation communities mapped per landscape unit in 2007 and 2010. Landscape units are ordered from south to north

Diversity associated with vegetation communities has remained relatively stable between 2010 and 2012. Minor increases in diversity were associated with Ptarmigan Creek and Yellow Jacket Creek with minor decreases at Beavermouth and Sullivan Arm (Figure 5-26). The apparent changes between 2007 and 2010 and 2012 are likely due to the changes in mapping that occurred between 2007 and 2010. Changes in diversity may be related to impacts from woody debris removal program in 2007 (Yellow jacket Creek) and high reservoir operations in 2007 (Beavermouth and Mount Blackman). The deposition of sediment in and erosion of the drawdown zone may also be contributing to changes in vegetation community diversity. Erosion events have been observed at Windfall Creek and sediment deposition is evident in regions of Bush Arm and at Hugh Alan Bay.

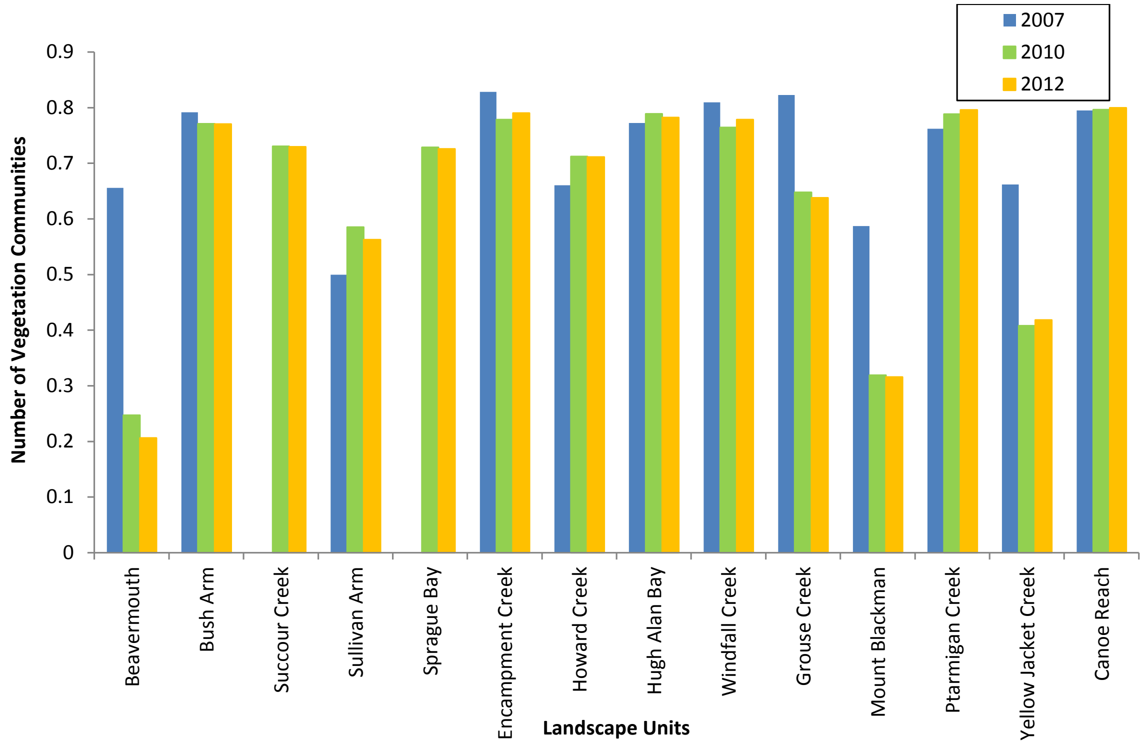


Figure 5-26: Diversity (Simpson's index) of vegetation communities mapped per landscape unit in 2007, 2010 and 2012. Landscape units are ordered from south to north

Table 5-8 details the changes in vegetation communities mapped for each landscape units between 2007 and 2012. Comparisons to 2008 are of limited utility due to the reduced area that was mapped in 2008 (see Hawkes and Muir 2008). See Figure 5-23 for a comparison of the relative contribution of each vegetation community to the total vegetated area of each landscape unit and year. Reductions in the total number of vegetation communities mapped per year and landscape unit are related to improvements in mapping that occurred in 2012. Changes observed in 2012 are related to the addition of vegetation communities at some landscape units (e.g., Ptarmigan Creek and Yellow Jacket Creek). It is likely that changes will be observed in future years, particularly in areas prone to woody debris accumulation. The effects of reservoir operations on the distribution and occurrence of vegetation communities in the drawdown zone will be assessed in part in 2013 (during field work for CLBMON-9 and more formally in 2014, which represents the next implementation year (2014).

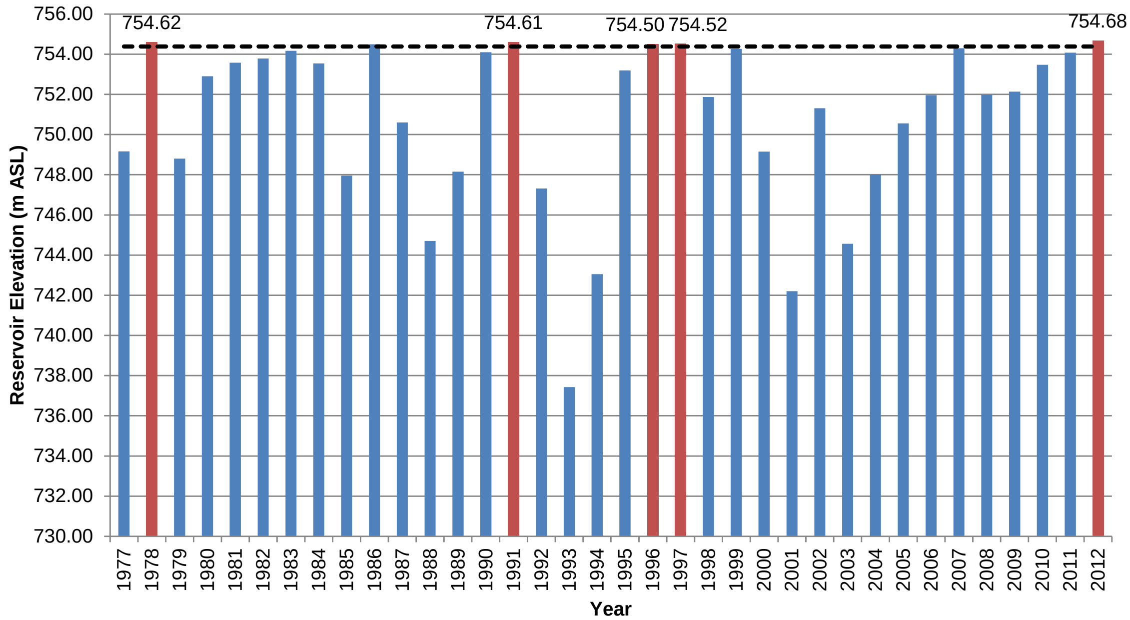
Table 5-8: **Presence of vegetation communities by landscape unit and year.** Shaded cells indicate the community was mapped for that landscape unit and year. The "total" column indicates the total number of communities mapped per year and the total row (e.g., Beavermouth Total) indicates the years communities were present in given landscape units

		Vegetation Community Code																			
Landscape Unit	Year	BR	BS	CH	CO	CT	DR	FO	KS	LH	LL	MA	MC	RC	RD	SH	TP	WB	WD	WS	Total
Beavermouth	2007			■	■	■	■		■							■					6
	2008			■	■	■	■		■							■					6
	2010			■	■		■														3
	2012			■	■		■														3
Beavermouth Total				4	4	2	4		2							2					6
Bush Arm	2007	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■		■	17
	2008	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	18
	2010	■	■	■	■	■	■	■	■		■	■		■		■	■	■		■	15
	2012	■	■	■	■	■	■	■	■		■	■		■		■	■	■		■	15
Bush Arm Total		4	4	4	4	4	4	4	4	2	4	4	2	4		4	4	4	1	4	18
Canoe Reach	2007	■		■	■	■	■		■	■	■		■			■	■		■	■	13
	2008	■		■	■	■	■	■	■	■	■		■	■		■	■		■	■	15
	2010	■	■	■	■		■		■		■				■	■	■	■	■	■	13
	2012	■	■	■	■		■		■		■				■	■	■	■	■	■	13
Canoe Reach Total		4	2	4	4	2	4	1	4	2	4		2	1	2	4	4	2	4	4	18
Encampment Creek	2007	■		■	■	■	■	■	■		■		■			■	■	■			12
	2008	■		■	■	■	■	■	■		■		■			■	■	■		■	13
	2010			■	■	■	■	■	■		■						■	■			9
	2012			■	■	■	■	■	■		■						■	■			9
Encampement Creek Total		2		4	4	4	4	4	4		4		2			2	4	4		1	13
Grouse Creek	2007			■		■	■			■											4
	2008			■	■	■	■		■	■											6
	2010			■					■	■											3
	2012			■					■	■											3
Grouse Creek Total				4	1	2	2		3	4											6
Howard Creek	2007			■	■	■		■	■												5
	2008			■	■	■	■		■												5
	2010			■		■	■	■	■												5
	2012			■			■	■	■												4
Howard Creek Totak				4	2	3	3	3	4												6
Hugh Alan Bay	2007	■		■	■				■		■					■					6
	2008	■		■	■		■		■		■										6
	2010	■		■	■		■		■		■										6
	2012	■		■	■		■		■		■										6
Hugh Alan Bay Total		4		4	4		3		4		4					1					7
Mount Blackman	2007			■	■	■	■				■										5
	2008			■		■	■		■		■										5
	2010			■	■																2
	2012			■	■																2
Mount Blackman Total				4	3	2	2		1		2										6
Ptarmigan Creek	2007			■	■	■		■	■		■						■				7
	2008			■	■	■		■	■												5
	2010			■	■	■		■	■		■						■				7
	2012			■	■	■	■	■	■		■						■				8
Ptarmigan Creek Total				4	4	4	1	4	4		3						3				8
Sprague Bay	2007																				
	2008		■	■	■	■	■		■		■		■			■		■		■	11
	2010				■	■	■	■	■		■							■		■	8
	2012				■	■	■	■	■		■							■		■	8
Sprague Bay Total			1	1	3	3	3	2	3		3		1			1		3		3	12
Succour Creek	2007																				
	2008	■		■	■	■	■	■	■		■		■			■	■	■		■	13
	2010	■		■	■	■	■	■	■		■						■	■		■	11
	2012	■		■	■	■	■	■	■		■						■	■		■	11
Succour Creek Total		3		3	3	3	3	3	3		3		1			1	3	3		3	13
Sullivan Arm	2007								■				■								2
	2008			■	■								■								3
	2010			■	■								■								3
	2012			■	■								■								3
Sullian Arm Total				3	3				1				4								4
Windfall Creek	2007			■	■	■	■		■		■					■					7
	2008			■	■	■	■		■		■					■					7
	2010			■	■	■	■		■		■										6
	2012			■	■	■	■		■		■										6
Windfall Creek Total				4	4	4	4		4		4					2					7
Yellow Jacket Creek	2007	■		■	■	■		■	■		■										7
	2008	■		■	■	■			■				■								6
	2010	■		■	■	■			■												5
	2012	■		■	■	■	■		■												6
Yellow Jacket Creek Total		4		4	4	4	1	1	4		1		1								9

5.2.3 Vegetation Communities, Inundation, and Climatic Variables

5.2.3.1 Reservoir Operations

The vegetation communities defined and classified in 2007, particularly those in the higher elevation bands (i.e., > 749 m ASL), had developed over a number of years when the reservoir did not reach full pool (Figure 5-27, Table 5-9). In 2008, the highest elevation band was not inundated; however, it is unlikely that trees or other woody stemmed plants would have had time to become re-established since 2007. If they had, the maximum reservoir elevations attained in 2011 would have likely contributed to the mortality of these plants. Results indicated previously that the richness and diversity of certain high elevation communities like the Willow-Sedge (WS; Figure 5-9, Figure 5-10, Figure 5-17) had decreased over time. The reduction of species richness and diversity of higher elevation plant communities is likely attributable to the operational regime of Kinbasket Reservoir since 2007, which included the near filling of the reservoir in 2007 and again in 2009. Between April 1 and September 30 2012, Kinbasket Reservoir was filled beyond the normal operating maximum of 754.38 m ASL for 33 days or 18 per cent of the growing season. The effects of this management on the vegetation communities in the drawdown zone will be examined in 2013 and 2014.



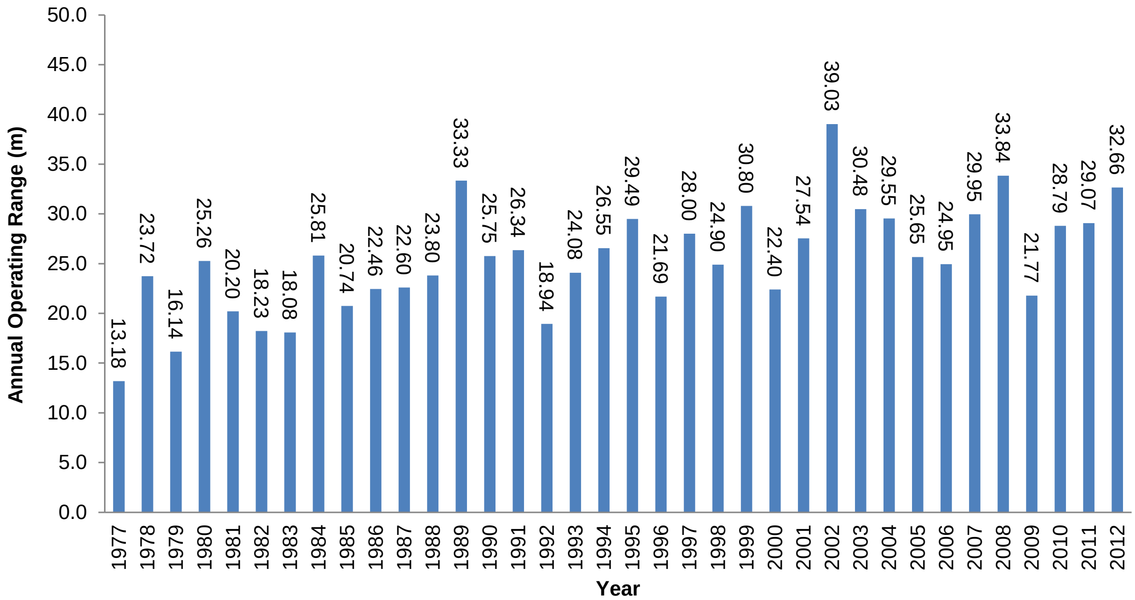


Figure 5-27: Maximum reservoir elevations recorded for Kinbasket Reservoir 1977 through 2012 (top) and annual draught (bottom). The black dashed line represents the normal operating maximum. Red bars indicate years when that maximum was exceeded

Table 5-9: Proportion of time that Kinbasket Reservoir elevations exceeded a particular elevation band (m ASL) for the months of April – September, 1997 – 2012. For example, in 1997, elevations between 741 and 742 m ASL were under water for 76.8 of 183 days (0.42 * 183 = 76.86). Shaded cells indicate that the reservoir did not exceed a given elevation band

	Year															
m ASL	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
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	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	0.53
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	0.52
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	0.51
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	0.50
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	0.49
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	0.48
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	0.46
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	0.46
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	0.45
751-752	0.26	0.29	0.29			0.23			0.16	0.43	0.40	0.18	0.16	0.19	0.38	0.44
752-753	0.24	0.14	0.27			0.06				0.37	0.36		0.06	0.03	0.35	0.43
753-754	0.21		0.22								0.19			0.01	0.32	0.32
>754											0.06				0.02	0.23
>754.38																0.18

5.2.3.2 Wet Stress and Dry Stress and Climatic Variables

The effects of wet stress and dry stress are considered in the context of water depth, frequency and timing of inundation, and exposure time (as a proxy for growing days). Not surprisingly, the average depth of water (as measured by the difference in reservoir water level and elevation on the ground) was greater for lower than higher elevations, with water depth decreasing linearly as elevation in the drawdown zone increased (Figure 5-28). Water depth in 2007 was approximately two metres higher at each elevation band than in 2010 and ~1.2 m lower than in 2012, illustrating how the reservoir was operated in 2007 (Table 5-9). Differences in average water depth were not statistically significant among years after controlling for elevation (i.e., only similar elevations were compared between years). Despite reservoir elevations varying from year to year, the rate at which the reservoir filled did not vary substantially in each implementation year with the exception of 2012, when the rate of filling was more rapid between at elevations > 750 m ASL (Figure 5-28). Kinbasket Reservoir filled more slowly in 2007, with 2008, 2010, and 2010 filling at a similar rate.

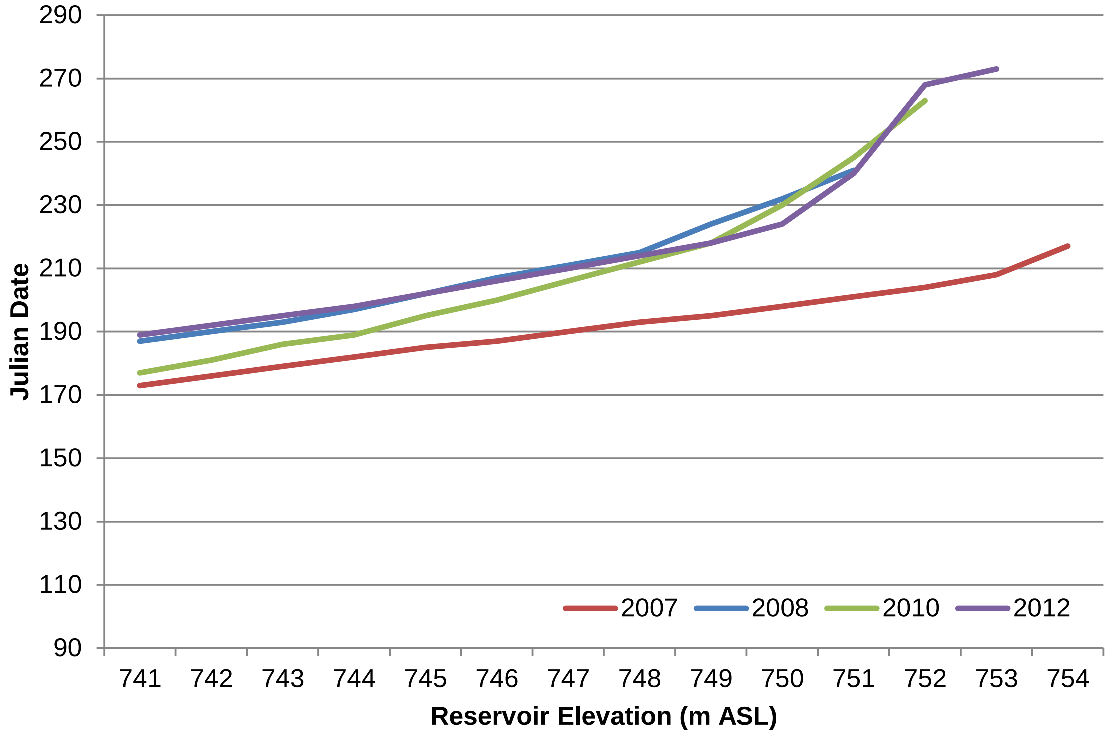


Figure 5-28: Rate of reservoir filling between 741 and 754 m ASL in 2007, 2008, 2010, and 2012

The frequency of inundation did not vary over time, with most elevations inundated once during the growing season (April through September) in all four implementation years. In both 2008 and 2010, Kinbasket Reservoir did not exceed elevations > 752 m ASL. 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. In general, the timing and depth of inundation were similar in 2008 and 2010, with the reservoir rising slightly later and reaching a lower maximum elevation in 2010 (Figure 5-29).

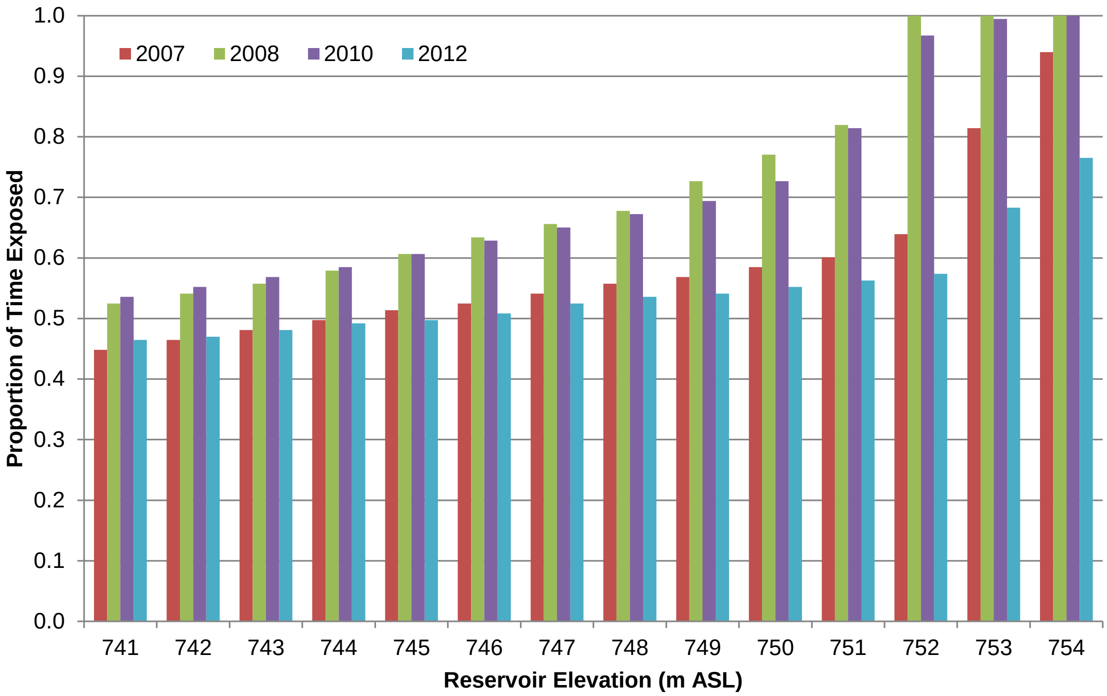


Figure 5-29: Proportion of days each elevation band was exposed to air in the drawdown zone of Kinbasket Reservoir between April 1 and September 30 (*n* = 183 days) in 2007, 2008, 2010, and 2012

In 2012 the reservoir filled more rapidly than previous years, reaching full pool several weeks earlier (Figure 4-1). The reservoir also exceeded the normal operating maximum for the first time since 1997 (Figure 5-27) and remained at elevations > 754.38 m ASL for 33 days. Although Kinbasket Reservoir was filled beyond the normal operating maximum in 2012, the draught of the reservoir in 2012 was not notably different than any other year in this history of Kinbasket (min: 13.18 m; max: 39.03 m; mean: 29.44 m; Figure 5-27). The effects of filling the reservoir beyond the normal operating maximum will be assessed in future implementation years. We anticipate that there will be impacts to the upper elevations (i.e., > 753 m ASL) resulting from erosion and from the mortality of woody plants.

The relationship between timing of inundation and the proportion of time elevation bands were exposed during the growing season (April 1 and September 30; n = 183 days) is shown in Figure 5-29. In 2010, the lowest elevation bands (741–744m ASL) had slightly more growing days than 2008, and in both years, were exposed longer than in 2007. In 2008, elevations between 746 and 751m ASL were exposed longer than they were in 2010, although as with the lowest elevation bands, the difference is marginal. The proportion of the growing season when all elevations bands were exposed was much lower in 2007 than in either 2008 or 2010. The overall number of exposed days was lowest for 2012 followed by 2007, 2010, and 2008. The most notable difference in 2012 was the reduced exposure time for elevations between 745 and 754 m ASL, which is where most of the vegetation communities mapped for the drawdown zone of Kinbasket Reservoir occur (see Hawkes et al. 2010).

Average monthly temperatures across the growing season (April 1 through September 30) were similar during all implementation years of CLBMON-10 (Table 5-10), with 2012 being slightly warmer than previous years. Relative humidity (per cent) was also similar across all years. Total precipitation was highest in 2010 and lowest in 2008. The minimal variation observed across the growing season with respect temperature, precipitation, and relative humidity is not likely to have strongly influenced vegetation establishment or development in the drawdown zone of Kinbasket Reservoir. Growing conditions are more likely to be influenced by exposure time, which is directly related to reservoir elevations.

Table 5-10: Average temperature (°C), relative humidity (%) and precipitation (mm) associated with the exposed elevation bands in April and September 2007, 2008, 2010, and 2012

	Temperature (°C)				Relative Humidity (%)				Precipitation (mm)			
Month	2007	2008	2010	2012	2007	2008	2010	2012	2007	2008	2010	2012
April	4.3	2.8	5.3	4.9	71.2	64.9	64.4	75.4	47.4	14.7	45.6	82.2
May	10.4	10.9	9.1	9.3	61.5	63.6	60.3	60.7	26.9	21.3	34.8	10.2
June	13.7	13.3	13.7	12.8	69.8	65.4	63.8	73.6	39.0	40.3	65.6	134.0
July	18.4	15.5	16.4	17.4	62.8	66.2	61.8	70.0	26.6	49.2	76.8	70.4
August	14.0	15.1	14.7	15.8	74.6	70.2	72.7	72.7	43.3	63.4	119.2	35.4
September	9.6	10.0	9.5	11.6	77.3	77.0	84.9	74.1	64.9	29.7	196.8	17.8
Mean or Sum	11.7	11.3	11.4	12.0	69.5	67.9	68.0	71.1	248.1	218.5	538.8	350.0

To assess the capability of vegetation growth during the growing season, the number of growing days per month and year were assessed relative to reservoir operations. The proportion of growing days available to each elevation band, month, and year for the growing season (April 1 through September 30) is shown in Figure 5-30. All elevations were exposed for most of or all of April, May, and June each year with exposure time decreasing in July and August. The reduction in exposure is related to increasing reservoir elevations, and affects the proportion of growing degree days available to plants. By August most of the area between 741 and 751 m ASL is under water. As this point, the proportion of growing degree days is assumed to be 0 per cent.

Figure 5-30 clearly shows that in the mid-summer growing months of June, July, and August, there was a substantial reduction in the proportion of available growing days in 2007 and 2012 relative to 2008 and 2010. The effect of reduced growing degree days on vegetation community establishment and development has not yet been studied, but it is likely that the increase in reservoir elevations and corresponding reduction of growing degree days limits the vegetation growing in the drawdown zone of Kinbasket Reservoir.

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

Figure 5-30: Proportion of growing days available during the growing season (April 1 through September 30) for each implementation year of CLBMON-10 for elevations between 741 and 754 m ASL. Green indicates little or no impacts on exposure time, yellow indicates a moderate to strong effect, and red indicates strong to complete reduction in growing degree days

5.3 Red- and Blue Listed Plants

Since 2007, we have documented the presence of seven blue- or red-listed plants in and adjacent to the drawdown zone of Kinbasket Reservoir. Five of these species were recorded in 2012 (Table 5-11).

Table 5-11: Scientific and common names, and BC Conservation Data Center (CDC) ranking, for the rare plants documented in the drawdown zone of Kinbasket Reservoir between 741 and 754 m ASL in 2007, 2008, 2010, and 2012. Y = Yes; N = No.

Scientific Name	Common Name	BC CDC Status	Years Documented			
			2007	2008	2010	2012
Carex crawei	Crawe's Sedge	Red-listed	Y	Y	N	Y
Carex tonsa[1]	Bald sedge	Blue-listed	Y	N	N	Y
Eleocharis elliptica	Elliptic spike rush	Blue-listed	Y	N	Y	Y
Liparis loeselii	Yellow widelip orchid	Red-listed	Y	N	Y	Y
Mimulus breviflorus	Short flowered monkey flower	Red-listed	Y	Y	Y	N
Mimulus breweri	Brewer's monkey flower	Blue-listed	Y	N	Y	Y
Packera plattensis[2]	Plains butterweed	Yellow-listed	Y	Y	Y	Y
Juncus stygius[1]	Bog rush	Blue-listed	--	--	--	Y
Dryopteris cristata[1]	Crested wood fern	Blue-listed	--	--	--	Y
Muhlenbergia glomerata[3]	Marsh muhly	Blue-listed	--	--	--	--

[1]Not documented in the drawdown zone, but did occur adjacent to the area of interest in Canoe Reach, near the Valemount Peatland.

[2]*Packera plattnesis* (formerly *Senecio plattensis*) was recently down-listed from blue to yellow.

[3] *Muhlenbergia glomerata* observed in 2011 during field work for CLMBON-9.

None of the plants in Table 5-11 have COSEWIC designation, nor are status reports being prepared. However, *Mimulus breweri* is currently listed as a Priority 2 candidate species, indicating that this species is Globally Rare (G3) or Subnationally Historic, Extremely Rare or Very Rare (SH, S1 or S2) across Canada. COSEWIC candidate species are species not yet assessed by COSEWIC that have been identified by COSEWIC as potentially being at risk. As such, they are candidates for detailed status assessment. *Packera plattensis* (formerly *Senecio plattensis*) was recently down-listed from Blue to yellow, meaning that populations of this species are presumed stable in British Columbia. Data collected for CLBMON-10 contributed to an increased understanding of the current distribution of this species in BC.

6.0 DISCUSSION

6.1 Summary

The 2012 field season represented the fourth year of an anticipated ten year program to monitor the vegetation communities found in the drawdown zone of Kinbasket Reservoir. The highly dynamic conditions within Kinbasket Reservoir have presented some challenges with respect to quantifying the direction and magnitude of change that vegetation communities are undergoing; however, the analyses performed in 2012 revealed some interesting patterns.

Since 2007, we have characterized and mapped 19 vegetation communities in the drawdown zone (Table 4-1). We have also recorded 291 plant species (including 42 species in 2012 not previously recorded). Given the dynamics of the reservoir, it is likely that new species will continue to be recorded from the drawdown zone during subsequent years. The total spatial extent of vegetation communities mapped in 2012 differed significantly from that in 2007, although much of the difference was attributable to mapping errors in 2007. The spatial extent of communities in 2012 was largely unchanged from 2010. In general, most communities appeared to be persisting in the drawdown zone and our data do not suggest a dramatic change in spatial extent and composition in those communities, at least not from the perspective of being able to use the classification methods developed in 2007 to classify communities in 2012. At the same time, species constancy (the proportion of all species observed in 2012 that were also recorded in both 2007 and 2012) was rather low, averaging 44 per cent for repeat transects and 22 per cent for entire communities. This implies either that species compositions are fluid and apt to change between census periods (a possibility given the highly dynamic conditions), or that species detectability rates are low. Low detectability could be due to one or a combination of annual transport and deposition of sediment, natural non-emergence in some years, cryptic growth forms, survey timing with respect to phenology, or simple observer oversight. Regardless, in this case, low species constancy is probably due to a combination of high species turnover rates and low detectability of some species.

Possibly as a consequence of the shifting species compositions, ordination analyses (PCA and RDA) applied to vegetation and environmental data from sample transects were only moderately effective at recreating the original community classifications, successfully relating some, though not all, of the communities delineated in the drawdown zone to the major species associated with those communities. Some of these disparities may also be related to the rate at which the reservoir filled in 2012, which precluded sampling across many elevations, particularly those below 751 m ASL. While these results do not impugn the validity of using the vegetation communities defined in 2007 with the 2012 data, they do suggest that additional time series data are needed to further refine our picture of reservoir plant compositions. Full characterizations of some communities may require adaptive redefining (or at least fine-tuning) in subsequent study years. These results also suggest that additional (and more informative) environmental variables (e.g., soil moisture and nutrient regimes) may be required in the future to adequately describe or predict plant community assemblages on the landscape.

Summer peak levels in the Kinbasket Reservoir have varied over the period of study; the filling of the reservoir to operating maximum in 2007 (for the first time since 1999) provided an unexpected opportunity to monitor inundation impacts on vegetation following a rare full pool event. The vegetation communities defined and classified in 2007, particularly those in the higher elevation bands (e.g., > 749 m ASL), had developed over a number of years when the reservoir did not reach full pool (Table 5-9). In 2008 and 2010, changes were noted to the vegetation communities that occur in the higher elevation bands (i.e., > 749 m ASL), particularly those containing an abundance of woody stemmed species such as shrub and tree species (Hawkes *et al.* 2010). High water levels in 2007 appeared to contribute to a die-off of these woody plants (and possibly other plant species as well; Hawkes *et al.* 2010). Since 2007, annual peak water levels have continued to be higher, and the inundation periods longer, than those experienced during the half decade prior to 2007. Concurrent with this trend, we have observed marked decreases in both species richness and diversity (Shannon H) since 2007, both at the transect level and at the landscape unit level. Much of this change is concentrated along the upper elevation bands of the drawdown zone, consistent with lingering impacts stemming from recent high water events.

Vegetation communities that occur at lower elevations in the reservoir regularly experience a greater degree of inundation relative to those that occur at higher elevations and thus it can be presumed that their formation and development has been largely governed by factors surrounding wet stress. In theory, these communities should be better adapted to tolerate occasional increases in inundation depth and duration than communities that developed at higher elevations and whose development, presumably, has been modulated to a greater extent by dry than by wet stress. Depth, duration, and timing of inundation have all varied across time in Kinbasket Reservoir (Section 5.2.3.2); only the frequency of inundation has not varied substantively. As might be expected, increased inundation appears to have negatively influenced vegetation communities occurring at higher elevations more than those at lower elevations. Although species richness and diversity are generally lower for communities occurring lower in the drawdown zone, richness and diversity of transects sampled at these lower elevations have remained relatively constant since 2007.

The timing and duration of inundation also influences the number of growing degree days (GGDs) available to vegetation in different zone of the reservoir. In the mid-summer growing months of June, July, and August, there was a substantial reduction in the proportion of available growing days in 2007 and 2012 relative to 2008 and 2010, consistent with the full pool events in those years. In the absence of other environmental stresses (such as moisture deficits or wet stress), the development rate from emergence to maturity for many plants depends upon the daily air temperature, and can often be predicted on the basis of GGDs. In the case of reservoir vegetation, it would be difficult, without direct experimentation, to separate out the relative importance of wet stress and GGDs in modulating patterns of plant distribution and abundance on the landscape. Nevertheless, it is quite likely that the patterns of plant zonation within the reservoir have been set at least in part by prevailing GGDs, such that periodic reductions in GGDs (as seen in 2007 and 2012) may prove to be an important factor that ultimately limits the capability of certain vegetation communities to expand in spatial extent, or of new communities to become established.

6.2 Community Dynamics

To illustrate the possible influence of reservoir operations on vegetation communities, we can review the structural trajectories of three communities that appear to be trending in nonparallel directions (Section 5.1.5): the Lady's Thumb-Lamb's-quarter (LL), Cottonwood-Trifolium (CT), and Clover-Oxeye Daisy communities. LL occurs within the lowest vegetated zone of the reservoir, whereas CO and CT are restricted to the upper elevation zones (Figure 5-17). LL is an early seral community characterized by ruderal species such as Lady's Thumb (*Polygonum persicaria*), Lambs-quarters (*Chenopodium album*), Purslane Speedwell (*Veronica peregrina*), and Common Knotweed (*Polygonum aviculare*); CT is a late (relative to other communities in the drawdown zone) seral community characterized by a high deciduous shrub cover as well as a high diversity of perennial herbs (Hawkes *et al.* 2007); and CO is a mid-seral community dominated largely by herbaceous annual and perennial weeds. In the three years after 2007, there was a statistically significant increase in plant diversity (as measured by Shannon's H) on transects sampled in LL, with most of this change occurring between 2007 and 2010. Diversity on transects within CT, on the other hand, declined between 2007 and 2010 (though the difference was not statistically significant), before slightly increasing again between 2010 and 2012 (Figure 5-10). Diversity within CO was stable following 2007, but dropped significantly after 2010.

The diversity trajectories associated with the LL, CT, and CO communites could plausibly be related to the string of high water events since 2007. The subsequent heavy sediment deposition that we observed in some landscape units in 2008 may have helped to open up new habitat patches while simultaneously transporting seeds of various plant species to the elevation bands associated with the LL community. A portion of this banked seed may have eventually germinated, leading to the spike in species diversity observed in 2010 in the LL community (as well as in other low-lying, early seral communities such as the TP).

In contrast, vegetation communities in the higher elevation bands such as CT had, by 2007, come to be largely dominated by woody stemmed shrubs and small trees as a result of several years of low peak water levels (never exceeding 752 m ASL; Figure 5-27) that may have facilitated their establishment and growth. Some upland woody species (e.g., Trembling Aspen, Soopolallie, Spruce, Douglas-fir), along with a number of graminoids and herbaceous perennials, were not recorded in the 2010 or 2012 sampling sessions, suggesting they failed to survive the 2007 full pool event and/or subsequent near full pools in 2010 and 2011. At the same time, several species more typically associated with wetland communities, and not seen previously, were observed in CT transects in 2012. These species included Mountain alder (*Alnus incana*), Douglas' Water-hemlock (*Cicuta douglasii*), Marsh Cinquefoil (*Comarum palustre*), Swamp Horsetail (*Equisetum fluviatile*), Tufted Lossestrife (*Lysimachia thyrsiflora*), and Small Bedstraw (*Galium trifidum*). The apparent replacement of some upland plants by more hydrophytic species within the CT could reflect the heavier flood regimes of the past few years, and may also help to account for the partial rebound in diversity recorded for this community in 2012.

It is more difficult to offer a simple explanation for the decrease in diversity within the CO community, as the decrease does not appear to be directly linked to the 2007 full pool event. However, it is worth noting that the distribution of this community is concentrated around the 752 m ASL elevation band, a band that generally escaped flooding between 2000 and 2006. Between 2007 and 2011, this elevation band was completely inundated in three out of five years. While many of the weedy species that had established within the CO community could perhaps withstand a single inundation event (i.e., 2007), they may have had more difficulty withstanding a sequence of inundation events such as they experienced between 2007 and 2011, eventually leading to the significant decline in species richness and diversity observed in 2012. However, it should also be noted that the sample size for this community in 2012 was small, with only three transects sampled compared to 16 transects in 2010. There is thus a real possibility that some of the apparent decrease in diversity is actually an artififact of sampling, and this should be taken into account.

For any of these cases it is, of course, difficult to establish cause and effect relationships with any certainty on the basis of observations made two years and five years following a single full pool event (2007). The unusually early and rapid flooding that occurred in 2012 also prevented worker access to all the areas that were earmarked for sampling, affecting our ability to draw comparisons between 2012 and other years. At the same time, the extreme high water event of 2012 will provide in additional opportunity in subsequent implementation years to track post-inundation impacts across all elevation bands

6.3 Landscape Units

For certain landscape units (e.g., Sullivan Arm and Windfall Creek), the full pool event is the most likely explanation for the apparent reduction in species diversity between 2007 and 2010. The elevation range at these landscape units is less than in places like Bush Arm and Canoe Reach and more importantly, the elevation of these landscape units is generally higher. In these cases, more woody-stemmed plant species were documented at these sites. As such, the die-off associated with the full pool event would have had a larger impact on vegetation at these landscape units. In addition, observations made in the field suggest that sedimentation was greater at these landscape units compared to others (although this has not been investigated in great detail), which is likely to have affected species diversity. The full pool event of 2012 creates a potential future opportunity to make a more thorough assessment of sedimentation potential at different elevation ranges to better address the reduction in species diversity associated with certain landscape units.

Prevailing wind patterns could explain some of the variation in species richness and diversity of some lower-elevation communities within certain landscape units. While we lack data on sediment transport and seed movements that would be needed to test this hypothesis, the prevailing wind direction in Canoe Reach has typically been to the northwest, i.e., up the reach (Figure 3-1, Figure 6-1). Assuming that the prevailing wind in Bush Arm is the same, wind could plausibly contribute to the increased species richness and diversity observed for some lower elevation communities such as TP. Interestingly, prevailing wind direction at the southern end of Canoe Reach (Howard weather station) was nearly exactly opposite that recorded at the northern end of the Reach (Valemount) in 2012, and also with respect to previous sampled years at Howard (Figure 6-1). Such a shift could affect future, near-term species composition at nearby landscape units such as Howard Creek, Windfall Creek, and Grouse Creek.

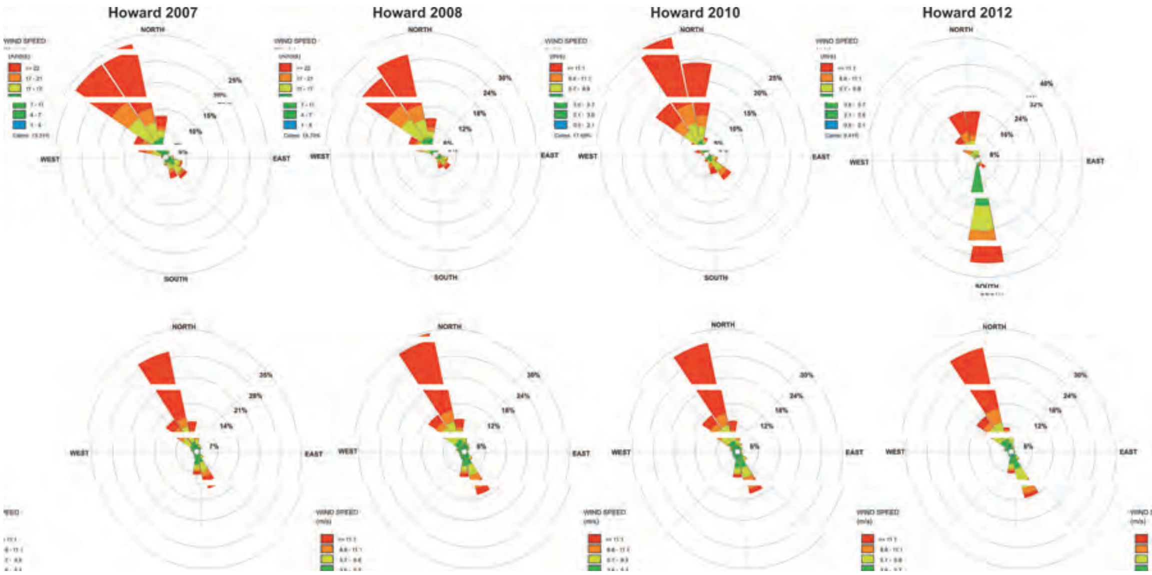


Figure 6-1: Wind speed and direction of prevailing winds in Canoe Reach for the period April 1 through September 30 in 2007, 2008, 2010 and 2012. Data provided by the BC Wildfire Management Branch. Figures generated in WRPlot View

At the mapping level, and as noted above, there was little change between 2010 and 2012 in the spatial extent of vegetated areas within landscape units. However, the spatial extent of vegetation did change for some of the defined communities within landscape units. The non-vegetated communities classified as Driftwood (DR) and Wood Debris (WD) both increased in area, possibly as a result of the lack of woody debris control (i.e., collection and burning) since 2007. The increase in DR was quite substantial at 30 per cent. This increase in areas affected by wood debris may have come at the expense of the MC, BS, and RC communities, which all decreased slightly in area in 2012. The MC (Mixed Conifer) community is situated in the upper elevation band, just below the forest edge while the BS (Buckbean-Slender Sedge) is a wetland association often found in low-lying depressions, both areas where driftwood is prone to accumulate. Because the observed decreases (11 to 13 per cent) fall very close to the minimal level of change detectable with GIS mapping, however, the severity of impact increased driftwood had on these communities is difficult to gauge.

6.4 Effect Size and Detection of Differences

As noted in Hawkes *et al.* (2010), the distinction needs to be made between effect size and the detection of differences in spatial extent associated with the mapping. Effect size is a measure of the strength of a relationship ones aims at detecting by performing statistical analyses. In the context of a multivariate, multi-year, multi-scale, highly complex study as CLBMON-10, conducted in a highly dynamic reservoir, determining precisely (or even generally) the effect size of all dependent variables involved represents a considerable challenge.

Effect size must not be confused with the error associated with detecting changes in vegetation communities at the landscape level. For example, as seen in this report, differences in aerial photography quality between 2007 and 2010 induced differences in spatial extent that are not necessary “real” (i.e., the differences are due to the mapping differences, not to biological phenomena). In other words, the detection of differences in the spatial extent of vegetation communities determined by the mapping exercise is a reflection of the level of error attributed to the exercise rather than to the level of change that the statistical analyses will be able to detect.

Given that the spatial extent of vegetation communities is computed directly from our statistical populations, which is comprised of all polygons delineated in the drawdown zone, we are dealing with a census of our population. Thus, any change detected does not need to be tested statistically, but discussed in terms of biological significance. In the next implementation year (2014) we will use data collected from 2007 to 2014 to assess the variability associated with each of the dependent variables (i.e., spatial extent, structure, and composition). This assessment will help us determine more precisely what level (or rate) of change is biologically meaningful. Furthermore, using the level of variation in the data associated with each dependent variable we will be able to derive an estimation of the effect size and achievable power based on the four years of data. The rate of change will be based on the variability observed so far in the dependent variables assessed. Even though it is unknown whether the variation observed up to 2014 will be similar to that observed at the end of the ten years of study, it will provide an estimation of the effect size and achievable power.

Several methods exist to determine power based on various effect sizes (size of effect and inherent variation of variables as described by standard deviation) and sample sizes (Bratcher *et al.* 1970, Sokal and Rohlf 1995, Kutner *et al.* 2005). It is worth noting however that even though we may achieve high power to detect (small or large) effects in various dependent variables, power does not provide an indication of the ability to link the potential changes observed for one or more the dependent variables to any of explanatory variables, whether they be environmental, inundation, climatic and/or spatial variables, especially in the context of such a dynamic, multivariate system.

7.0 CONCLUSIONS

Many of the conclusions reached in the last implementation year (Hawkes *et al.* 2010) were supported in the current implementation year. If Kinbasket Reservoir is operated such that near filling occurs annually or semi-annually, we will likely see a further reduction in species richness and diversity of communities situated in the upper elevation bands of the drawdown zone. The communities situated in the lower and mid elevation bands (i.e., < 749 m ASL) appear to have adapted to varying water depth, timing of inundation, and duration of inundation (i.e., varying wet and dry stress), and as such, have adapted to the way the reservoir has been operated since 1976. Although changes in these communities' spatial extent, structure, and composition are expected, the magnitude of changes is anticipated to be small compared to changes that are likely to occur between 752 and 754 m ASL if operations continue as they have. At the current rate of occurrence of full pool to near full pool events (i.e., every other year or so), many of the woody stemmed species are unlikely to remain established at the upper elevations, resulting in long-term changes to the communities occupying those elevation bands. Because the current operating regime of the reservoir includes irregular full pool events, communities in the upper elevations are not likely to ever find equilibrium, because they will be trying to adapt to variable water depth and duration of inundation on an annual or semi-annual basis.

For the most part, the methods implemented to date will enable the collection of an adequate amount of data that can be used to address each hypothesis in turn; however, for all hypotheses, a time-series of data is required before the hypotheses linked with the broader management questions can be tested statistically.

Table 7-1 summarizes the management questions and hypotheses associated with CLMBON-10 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.

The spatial extent, structure, and composition of the vegetation communities delineated in the drawdown zone has not changed remarkably since 2007; however, subtle changes to specific vegetation communities likely related to reservoir operations may manifest themselves into larger landscape level changes that will only be determined after at least several more years of study. Improvements associated with the acquisition of aerial photos in 2010 and 2012 resulted in a much-improved set of vegetation polygons, which can be used as the basis for future comparisons. Furthermore, the 2007 polygons were revised (in terms of spatial delineation and polygon labels) to the 2010 imagery, providing a more reliable and accurate base against which future comparisons can be made.

Finally, the dynamic nature of sediment transport and deposition in Kinbasket Reservoir suggests that there will be annual changes in species richness, diversity, and evenness of vegetation communities; it will likely be challenging to attribute those changes strictly to reservoir operations. However, certain operational-related outcomes such as periodic full pool events (following multiple years of lower maximum reservoir elevations) and periodic, large-scale woody debris removal programs (that temporarily affect substrates of the drawdown zone), are particularly likely to provide valuable opportunities in the future for relating changes in the extent, structure, and composition of vegetation communities to reservoir operations.

Table 7-1: Summary of the relationship between the management questions and management hypotheses associated with CLBMON-10. A brief summary of the data required, current status, and (key) preliminary results are provided

Management Question (MQ)	H0	H0A	H0B	Will MQ Be Addressed?	Data Required	Current Status	Preliminary Results
i. What are the existing riparian and wetland vegetation communities in the Kinbasket Reservoir drawdown zone between elevations 741 m to 754 m?	H0			Yes	Aerial Photography, Field data (transects)	Most, if not all communities occurring in the drawdown zone have been characterized	18 communities delineated in 2007 and 2008. 19 in 2010 and 2012.
ii. What is the spatial extent, structure and composition (i.e., relative species distribution and diversity) of each of these communities within the drawdown zone between elevations 741 m to 754 m?		H0A		Yes	Vegetation community delineation, field data, GIS data	Metrics related to species richness, diversity, and evenness have been computed based on field data collected in 2007, 2008, 2010, and 2012	19 communities have been described for the drawdown zone and the distribution of those communities relative to substrate and elevation has been described. The spatial extent is affected by reservoir operations, particularly when the reservoir exceeds full pool. With additional years of data a temporal assessment of how the spatial extent of the vegetation communities is related to reservoir operations can be made.
iii. How do spatial extent, structure and composition of vegetation communities relate to reservoir elevation and site conditions (aspect, slope and soil drainage)?		H0A		Yes	Vegetation community delineation, field data, GIS data, Site drainage data	Approaching ability to address all aspects of the management question	See above. Additional soil drainage data are required. The rate of reservoir filling in 2012 precluded data collection. Information obtained for CLBMON-61 may be adequate for this effort.
iv. Does the current operating regime of Kinbasket Reservoir maintain the spatial extent, structure and composition of existing vegetation communities in the drawdown zone?	H0	H0A	H0B	Yes	Time series data (minimum of five years)	After the 3rd year we are starting to see changes in certain communities that are likely related to the full pool event of 2007	At present it appears that most communities are persisting in the drawdown. A longer time series of data are required to adequately address this question. Reservoir operations do affect the number of growing degree days, which is limiting the establishment and development of vegetation communities in the drawdown zone of Kinbasket Reservoir.
v. Are there operational changes that can be implemented to maintain existing vegetation communities at the landscape scale more effectively?	H0	H0A	H0B	Yes	Time series data	See above.	The vegetation communities have developed in the drawdown zone under various operating conditions and appear to be somewhat adapted to this variation. To increase the spatial extent of vegetation between 741 and 754 m ASL would require filling the reservoir to < 741 to afford the vegetation at higher elevations time to develop. The current operation of the reservoir will probably contribute to a reduction in the spatial extent of vegetation communities.
H0: Under the current operating regime, there is no significant change in existing vegetation communities at the landscape scale in the drawdown zone of Kinbasket Reservoir over the monitoring period.							
H0A: There is no significant change in the spatial extent (number of hectares) of vegetation communities within the existing vegetated zones of Kinbasket Reservoir.							
H0B: There is no significant change in the structure and composition (i.e., species. distribution and diversity) of vegetation communities within the existing vegetated zones of Kinbasket Reservoir.							

8.0 RECOMMENDATIONS

The following recommendations are based on the first three years of study results:

1. Continue the program through 2016 to. This is required to characterize the variability in vegetation communities of the drawdown zone and to determine if reservoir operations maintain the existing spatial extent, structure, and composition of those vegetation communities;
2. Time the aerial photo acquisition in 2014 to coincide with the same phenological stage of vegetation growth in the drawdown zone. This will ensure a direct comparison of vegetation communities from 2007 to 2012;
3. Continue to acquire aerial photos digitially;
4. Obtain quantitative data on soil moisture to further develop our understanding of how spatial extent, structure and composition of vegetation communities relate to reservoir elevation and site conditions (aspect, slope and soil drainage);
5. Implement field sampling in 2014 when plant growth is as advanced as it was in 2010 and 2012. Periodic assessments of plant phenology will be made during field work for other studies (e.g., CLMBON-37, CLMBON-61); and
6. Maintain the level of ground truthing between 12 and 15 per cent of the total number of polygons to be consistent with previous years.

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10.0 APPENDICES

Appendix 10-A. Example of data card used to record vegetation and associated site-specific information along transects sampled in 2010

Project ID	**CLBMON-10: Kinbasket Reservoir Inventory of Vegetation Resources**						
Date		**DDZ ☐ UPL ☐ RIP ☐**	**Transect #**		**Quadrat #**		**Tran Brg:**
Surveyors		**Landscape Unit:**	**VCC**		**Photo Nos.**		

Vegetation Cover	**%**	**TREE LAYER (A)**									
Tree Layer (A)		**Spp**	**A1**	**A2**	**A3**	**Tot**	**Spp**	**A1**	**A2**	**A3**	**Tot**
Shrub Layer (B)											
Herb Layer (C)											
Moss / Seedling (D)											

SHRUB LAYER (B)											
Spp Code	**B1**	**B2**	**Tot**	**Spp Code**	**B1**	**B2**	**Tot**	**Spp Code**	**B1**	**B2**	**Tot**

HERB LAYER (C)						**Moss Layer**		**NOTES**
Spp Code	**%**	**Spp Code**	**%**	**Spp Code**	**%**	**Spp Code**	**%**	

SUBSTRATE Type (General) PRIMARY Rock ☐ Cobble ☐ Gravel ☐ Sand ☐ Silt ☐ Fines ☐ Wood ☐ **Percent:** ____
SECONDARY Rock ☐ Cobble ☐ Gravel ☐ Sand ☐ Silt ☐ Fines ☐ Wood ☐ **Percent:** ____
TERTIARY Rock ☐ Cobble ☐ Gravel ☐ Sand ☐ Silt ☐ Fines ☐ Wood ☐ **Percent:** ____

SUBSTRATE (Must Equal 100%)							
Organic Matter – Live		**Organic Matter - Dead**		**Decay Wood**		**Bedrock**	
Rock		**Mineral Soil**		**Water**		**Other**	

Appendix 10-B. Aerial photography metadata

Acquisition Date

- June 22nd and morning of the 28th , 2012
- Photos taken in optimum sun angles between 10:30am – 12:30pm and 1:30pm – 3pm.
- Photographed @ low water conditions (acquisition dates recommended by LGL)

Flight & Camera Details

- Vertically mounted aerial digital camera on gimballed mount
- Most western shore sites were flown in the morning hours so that tree shadow is not obscuring foreshore, most eastern shore sites flown in afternoon.
- All sites were flown at 9cm pixel size, subsequently reprocessed to 10cm in the mosaicking process.
- Area photographed is outlined in shapefile (VPmerged_Dissolve_2010.shp).
- GPS moving map display used for survey flight guidance.
- Pilot: Dave Chapin, Photographer: Jamie Heath

Camera Details & Calibration

- Alpa Metric medium format digital camera
- Focal length = 78.75mm
- Principle point offset: x= 0.058 y= -0.126
- Chip Size = 53.904 x 40.4mm
- Radial Distortion: K0= 5.31331e-007
- All photos taken as 16bit raw imagery, reprocessed to the optimum 8bit tiffs.

Aerial Triangulation / Ortho details

- Aerial triangulation completed by Aerometric (Alaska) and Terrasaurus.
- The existing 2008 orthophotos were used as ground control.
- Airborne GPS (ABDGPS) and IMU data was also used in the AT process.
- All colour balancing was completed by Terrasaurus using their proprietary colour program.
- Orthorectifying and mosaicking completed by Terrasaurus.
- A high resolution DEM was supplied by LGL (foreshore area only). Terrasaurus resampled the TRIM DEM and appended it to areas outside of the existing foreshore DEM for more complete DEM coverage.
- Map projection is UTM11, Nad83.
- All mosaics delivered in both Geotiff and ECW formats.

Site data

- All sites were photographed on June 22nd, 2012 except for the following sites: Beavermouth, Bush Mouth, and Bush Island. Those sites were captured on June 28th, 2012.
- The pond photos were also all captured on June 22nd, 2012, except for the ponds at Bush Mouth, Bush Island, and Bush Arm. Those sites were captured on June 28th.
- All photos are delivered with the exterior orientation data supplied