Columbia River Project Water Use Plan

Kinbasket and Arrow Reservoirs Revegetation Management Plan

Kinbasket Inventory of Vegetation Resources

Implementation Year 5

Reference: CLBMON-10

Final Report

Study Period: 2014

LGL Limited environmental research associates
Sidney, BC

June 22, 2015

EA3532

KINBASKET AND ARROW LAKES RESERVOIRS

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




Year 5 – 2014
Final Report

Prepared for

BC Hydro Generation
Water Licence Requirements
Castlegar, BC

BC Hydro Reference No. Q7-7123

Prepared by

Virgil C. Hawkes[1], M.Sc., R.P.Bio.

and

Pascale Gibeau[2], M.Sc., R.P.Bio.

[1]LGL Limited
environmental research associates
9768 Second Street
Sidney, British Columbia, V8L 3Y8

[2]Ripple Environmental
Vancouver, BC

June 22, 2015

LIMITED
environmental research associates

Suggested Citation

Hawkes, V.C and P. Gibeau. 2015. CLBMON-10 Kinbasket Reservoir Inventory of Vegetation Resources. Annual Report – 2014. LGL Report EA3532. Unpublished report by LGL Limited environmental research associates, Sidney, B.C., for BC Hydro Generations, Water License Requirements, Burnaby, B.C. 74 pp + Appendices.

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 Peatland; and Reed Canarygrass in Beavermouth. All photos © Virgil C. Hawkes, LGL Limited.

EXECUTIVE SUMMARY

2014 marked the fifth year of monitoring 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 2012, the most recent implementation year. Improvements associated with the acquisition of aerial photos between 2010 and 2014 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. The acquisition of LiDAR data in 2014 indicates that additional areas of the drawdown zone need to be mapped because of the level of disagreement between the BC Hydro produced digital elevation model and the LiDAR one. Some of these areas were mapped in 2014 to assess how much additional area might be added and for the areas assessed, and an additional ~ 100 ha of existing vegetation was delineated. This indicates that the total extent of vegetation in the drawdown zone is currently underestimated.

In 2014, the reservoir filled with similar timing and magnitude to previous years, but didn't quite reach full pool (compared to the surcharge achieved in both 2012 and 2013). The influence of reservoir operations on the structure and composition of vegetation communities was evident in 2014, with notable reductions since 2007 in species diversity and richness for communities occurring at the highest elevations of the drawdown zone (i.e., ≥ 750 m ASL) 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 and 2013.

The timing and duration of inundation also influence the number of growing degree days (GDDs) available to vegetation in different zones of the reservoir. In the summer growing months of June, July, and August, there was a substantial reduction in the proportion of available growing days in 2007, 2012, and 2014 relative to 2008 and 2010, consistent with the full pool and surcharge events in those years. It is difficult, without direct experimentation, to separate out the relative importance of wet stress and GDDs 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 GDDs, such that periodic reductions in GDDs (as seen in 2007, 2012 and 2014) 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 2014 that were also recorded in previous years) 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 MRT) applied to vegetation and environmental data from sample transects were only moderately effective at recreating the original 2007 community classifications. While these results do not impugn the validity of using the vegetation communities defined in 2007 with the 2014 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 2014 with respect to the management questions and management hypotheses is summarized in tabular form (below).

Management Question	Will MQ Be Addressed?	Current Supporting Results	Suggested Modifications to Methods Where Applicable	Sources of Uncertainty
i. What are the existing riparian and wetland vegetation communities in the Kinbasket Reservoir drawdown zone between elevations 741 m to 754 m?	Yes	18 communities delineated in 2007 and 2008. 19 in 2010, 2012 and 2014.	Not all areas of the drawdown zone with existing vegetation have been mapped, which underestimates the total area of existing vegetation. These areas should be included in future assessment of total vegetated area.	Because the entire drawdown zone has not been considered for CLBMON-10, only the areas identified as a priority for sampling in 2007 can be assessed relative to this management question.
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?	Yes	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.	Not all areas of the drawdown zone with existing vegetation have been mapped, which underestimates the total area of existing vegetation. These areas should be included in future assessment of total vegetated area.	The LiDAR data obtained in 2014 suggests that additional areas of the drawdown zone need to be mapped, particularly in areas > 751 m ASL. This would lead to increases in the total cover of vegetation and the addition of at least two new communities. Some areas were assessed based on the LiDAR data in 2014 and ~ 100 ha of additional habitat was mapped.
iii. How do spatial extent, structure and composition of vegetation communities relate to reservoir elevation and site conditions (aspect, slope and soil drainage)?	Yes	The relationship between reservoir elevation and species richness and diversity is starting to become clear: repeated years of high water or surcharging negatively affect these parameters. The spatial extent of most communities has remained stable over time, but some changes might be realized through the use of the LiDAR data and a longer time series of data.	The current duration of this monitoring program may not be long enough to properly assess the effects of repeated high water and surcharge events on existing vegetation.	The longer-term effects of surcharge or repeated years of high water are likely to have a negative effect on the spatial extent of existing vegetation communities, but this assumption requires testing.
iv. Does the current operating regime of Kinbasket Reservoir maintain the spatial extent, structure and composition of existing vegetation communities in the drawdown zone?	Yes	Current data suggest that the current reservoir operating regime (2007 - present) negatively affects species richness and diversity.	See above - the longer term effects of the operating regime on the spatial extent of existing vegetation communities needs to be assessed over an appropriate duration.	At present it appears that most communities are persisting in the drawdown. Longer time series of data are required to adequately address this question. Reservoir operations do decrease the number of growing degree days, which is limiting the establishment and development of vegetation communities in the drawdown zone of Kinbasket Reservoir.

Management Question	Will MQ Be Addressed?	Current Supporting Results	Suggested Modifications to Methods Where Applicable	Sources of Uncertainty
v. Are there operational changes that can be implemented to maintain existing vegetation communities at the landscape scale more effectively?	Yes	Given the effects of high water and surcharge a reduction in the maximum elevation and duration of inundation would function to maintain existing vegetation at higher elevations. It may be possible to implement physical works to either protect or create habitats in the drawdown zone, which could lead to the maintenance of vegetation communities.	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 maintain or 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.

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

ACKNOWLEDGMENTS

The authors acknowledge the assistance of Philip Bradshaw, Guy Martel, Margo Dennis, and Mark Sherrington of BC Hydro. Mike Miller, Jamie Fenneman and Jeremy Gatten (LGL) collected field data. Terra Remote Sensing acquired the digital aerial imagery and LiDAR data and produced the orthorectified imagery in 2014. Lucia Ferreira (LGL) completed the updates to the vegetation community classification. Julio Novoa and Lucia Ferreira (LGL) completed the GIS analyses associated with this project. Nathan Hentze and Krysia Tuttle (LGL) assisted with report preparation. Rodd Watt of Canadian Helicopters (Vernon BC) provided helicopter services in 2014.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

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 create complex disturbances 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 sediments, 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, Robertson 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, Hudon 2004, Van Geest *et al.* 2005, James *et al.* 2007, Watt *et al.* 2007, Della Bella *et al.* 2008, Hopfensperger and Engelhardt 2008, Wilcox and Nichols 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 regimes (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). 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). The seasonal timing of inundation affects plant establishment and diversity (Robertson *et al.* 2001, Budelsky and Galatowitsch 2004), as well as waterborne seed 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 (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). All of this cumulates in the importance of the relationship between the water regime of a site (e.g., wetland, floodplain, etc.) and the plant communities that exist and persist therein.

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 the 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 very 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 and often regular 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 (e.g. 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 their plasticity of response (Vervuren *et al.* 2003, Luo *et al.* 2007). Flood-sensitive species may be largely restricted to higher elevation regions of the floodplain where the impacts of flooding are reduced, while more tolerant species may persist in lower areas 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 six-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 levels 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, composition, and spatial extent within a specified elevation band of the drawdown zone of Kinbasket Reservoir under the standing operating regime over a seven-year period (2007–2014). 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 (BC Hydro 2007).

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; and (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.

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

[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.

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 km^2.

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., 2007–2014) occurring on both the east and west sides of the reservoir.

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

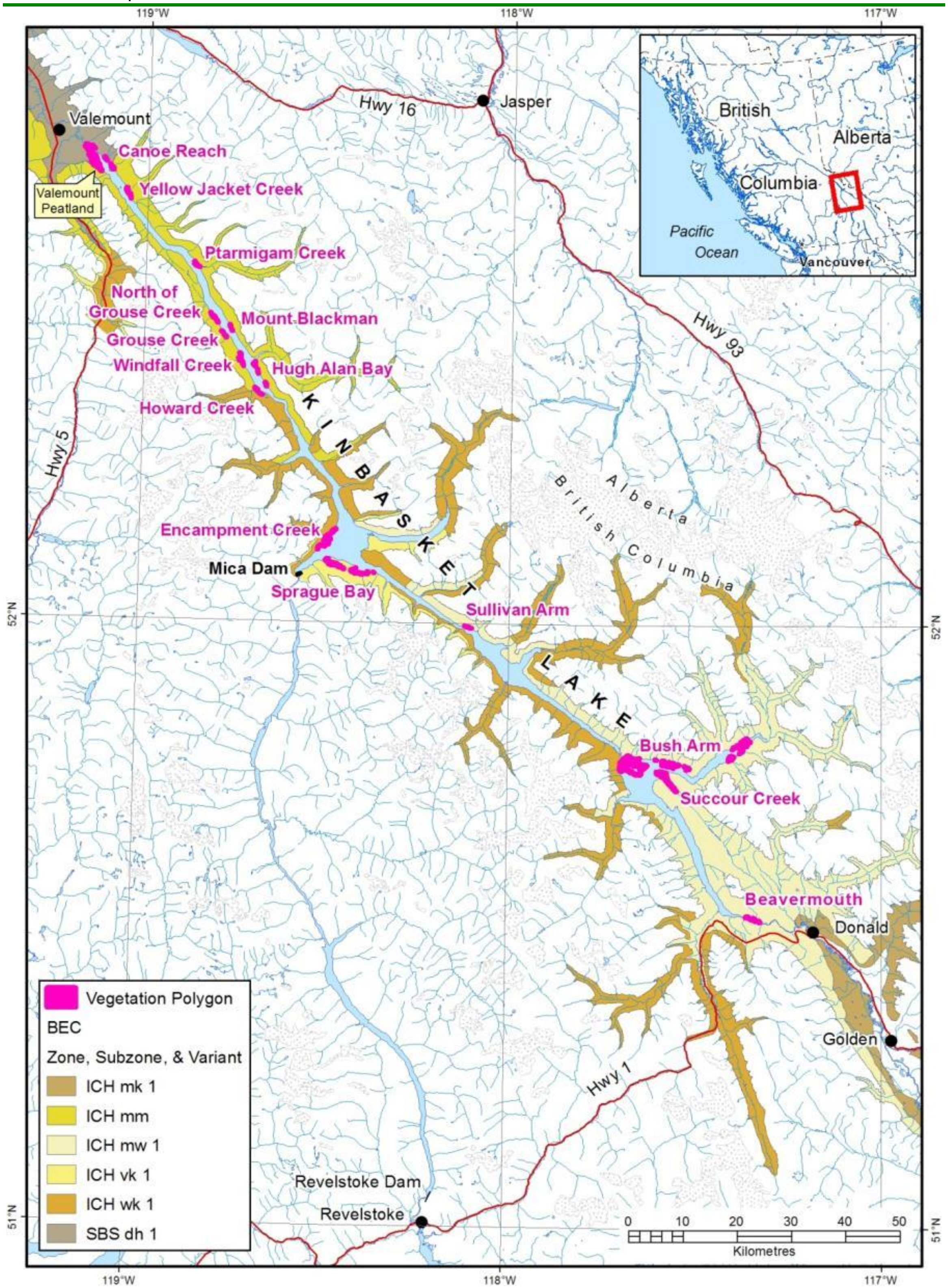


Figure 3-1: Location of Kinbasket Reservoir and vegetation sampling locations (pink). Landscape unit names (e.g., Beavermouth, Encampment Creek) were assigned to each area sampled in 2007. Pink areas also denote the locations of aerial photograph acquisition.

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, 2012). The present study is a longer-term monitoring program, spanning a period of ten years (2007–2016). During years 1, 2, 4, 6, 8 (2014), and 10, aerial photograph interpretation and field sampling are 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 intervals 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).

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

The following specific questions are addressed:

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.

Unique Species – Species that was sampled in only one transect, vegetation community, or landscape unit, in only one year.

4.2 Background

CLBMON-10 was initiated in 2007 with field sampling and aerial photography acquisition in years 1, 2, 4, and 6 (2007, 2008, 2010, and 2012). The results of each of those years of study can be found in Hawkes *et al.* (2007), Hawkes and Muir (2008), Hawkes *et al.* (2010) and Hawkes et al. (2013). A brief overview of 2007, 2008, 2010 and 2012 is provided below, and a more detailed account of 2014 (Year 8) follows.

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 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 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

Field sampling in 2012 followed the methods used in previous years. A total of 73 transects were sampled representing 14 vegetation communities and 12 landscape units. Aerial photos were captured digitally in 2012 and the delineation of vegetation communities was done in 2D using ArcGIS software. The vegetation communities delineated in 2007 were used as a baseline for 2012 (mainly because the entire study area was not photographed in 2008) and comparisons to 2007 and 2010 were made. The spatial extent of mapped vegetation communities differed significantly from 2007, but not from 2012. Differences between 2007 and 2012 were attributed to mapping errors made in 2007. Species constancy was relatively low at 44 per cent for repeat transects and 22 per cent for entire communities, which could be due to low detection rates or other factors (see Hawkes et al. 2013). Recommendations made in Hawkes et al. (2013) were implemented to the extent possible – it is not always possible to sample during optimal plant growth because of increasing reservoir levels.

4.7 Year 5 – 2014

The following methods describe the approach taken in 2014.

4.7.1 Vegetation Community Classification

We continued to use the same 15 vegetation communities and three 'other' (DR, WD, and FO) communities characterized in 2007 and 2010 to map the vegetation communities in 2014 (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. Note that only the SH community aligns

with site series classifications used in BC; the remainder are unique to the 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)

4.7.2 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 for vegetation communities in the drawdown zone (landscape unit, elevation, slope, aspect, soil moisture, soil texture, and soil nutrients), and on factors for which there are empirical or categorical data (e.g., 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 elevation 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	Successional 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
BS	Buckbean - Slender Sedge	late
WS	Willow - Sedge wetland	late
CT	Cottonwood - Trifolium	late
LH	Lodgepole Pine - Annual hawks beard	late
MC	Mixed Conifer	late

4.7.3 2014 Sampling Objectives

The objectives of the 2014 field sampling were: 1) to resample transects established in previous years; 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 2014.

4.7.4 Field Sampling

Field methods followed those of Hawkes *et al.* (2007), Hawkes and Muir (2008), and Hawkes et al. (2010 and 2013). 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 the field in 2014 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, general views of each transect, and of 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: 18–29 June and 11–22 July (*cf.* 26–29 June and 10–18 July in 2007, 18–25 June and 11–25 July 2008, 14–23 June and 12–26 July 2010 and 11–21 June and 16–26 2012). In 2014, 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).

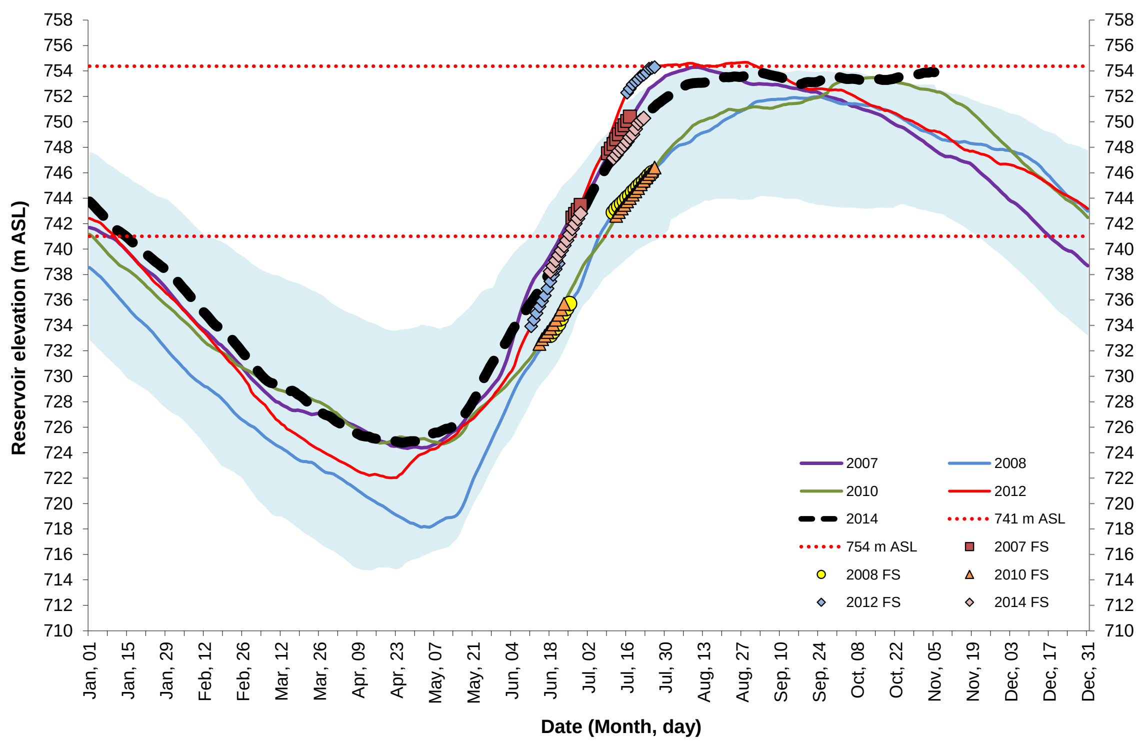


Figure 4-1: **Kinbasket Reservoir elevations (m ASL) in 2007, 2008, 2010, 2012 and 2014.** The shaded area indicates the 10th and 90th percentile 1976 to 2014. Timing of vegetation sampling (FS) is shown for each year. The 741 and 754 m ASL elevations are indicated.

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 2014. In 2014, we started with a selection of 108 transects representing 16 of the 18 vegetation communities defined for the drawdown zone of Kinbasket Reservoir, but because of rapidly rising reservoir levels, only 96 of the 108 transects were sampled (Table 4-3). At least one transect was sampled per vegetation community, with a maximum of 18 in the Common Horsetail (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 (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													
2014 VCC	**Beavermouth**	**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**
BR			2										1	**3**
BS		1												**1**
CH	1		3	5	1	1	2	2	1		2		2	**20**
CO		1	6	1		1					2		2	**13**
CT				3								1		**4**
DR								1						**1**
KS		2	3	2		1		1	3	1				**13**
LL		2	3	1		1			2	1				**10**
MA		3												**3**
RC		1												**1**
RD			2											**2**
SH		3	1											**4**
TP			1	1					1					**3**
WB		2	2	1						2				**7**
WD			1											**1**
WS		3	1											**4**
NOVEG*					1		1	1			1	2		**6**
Total	**1**	**18**	**25**	**14**	**2**	**4**	**3**	**5**	**7**	**4**	**5**	**3**	**5**	**96**

***** Indicates transect situated in area devoid of vegetation.

Transect locations were located in the field using a handheld 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.

4.7.5 Aerial Photo Acquisition and Interpretation

In 2007, aerial photographs were taken on May 30 and 31 (Figure 3-1) 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., more than 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 in 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. 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. Terrasaurus 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. Aerial photos and associated LiDAR data were provided by Terra Remote Sensing in 2014. All data were acquired on June 20 and 21, 2014. Reservoir elevations were 739.10 and 739.51 m ASL, respectively.

4.7.6 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 2012 were updated to the 2014 orthomosaics using a heads-up (i.e., on screen) approach where each polygon delineated in 2012 was assessed relative to the 2014 imagery. Based on the visual comparison of 2012 to 2014, polygons delineated in 2012 were either left unchanged, modified to fit the extent of vegetation cover on the 2014 images, or deleted (if there was no vegetation on the ground). The spatial extent and distribution of each vegetation community delineated in 2014 was compared to the 2007, 2010, and 2012 datasets to determine whether substantive changes in the occurrence of extent of vegetation had occurred. In addition to assessing the shape of each polygon relative to the 2014 imagery, additional areas of the drawdown zone were mapped above the existing 754 m ASL elevation contour (see discussion regarding the digital elevation model generated from the 2014 LiDAR data and BC Hydro data).

4.8 Variables Estimated, Data Summaries, and Statistical Analyses

Most data summaries and statistical analyses methods follow Hawkes et al. (2013). Only new methods as used in 2014 are summarized below.

4.8.1 Transect Data

General characteristics of the vegetation data sampled per landscape unit, elevation band, and vegetation community were described with a series of tables, graphs, figures, and statistical analyses. Per cent cover of vegetation species, species constancy, richness, diversity and evenness were computed and processed in the same ways as previously reported in 2012 (Hawkes et al. 2013), except that trends were based on four years of data (i.e., 2007, 2010, 2012, and 2014); data from 2008 were excluded from many analyses for reasons explained in the 2010 annual report (Hawkes *et al.* 2010).

One additional analysis was performed to complement the canonical analyses (RDA): Multivariate Regression Trees (MRT). MRT were used to further describe the environmental variables influencing the composition in vegetation species that characterized the transects in 2014. The response variables were the cover of the main species in the transects. The independent variables included were the same ones as used in the RDA (. Multivariate regression trees are interesting methods since they deal well with continuous or discrete variables, nonlinear relationships, complex interactions, missing values in both dependent and independent variables, and outliers (De'ath and Fabricious 2000, Moisen 2008). These characteristics often provide them with an advantage compared to canonical analysis (e.g. RDA) in the context of complex ecological datasets.

A multivariate regression tree results from the recursive partitioning of the response variables into a series of boxes (the leaves) that contain the most homogeneous groups of objects (in our case, of transects), constrained by the independent variables (De'ath 2002, Legendre and Legendre 2012). Creating the splits is constructed by seeking the threshold levels of independent variables that account for the greatest similarity among transects, and each group also corresponds to a species assemblage and its associated habitat (De'ath 2002). The amount of variation in the data explained by the tree is expressed in terms of cross-validation error (CV error), corresponding to the ratio of variation unexplained by the tree to the total variation in the dependent variables (Legendre and Legendre 2012). Pruning of the tree can be performed to eliminate the smallest (and less informative) branches, as decided by the cross-validation procedures (Legendre and Legendre 2012).

The trees are read from the top to the bottom. The variables that create the splits at each node are labelled with the threshold at which the splits occur. By reading the tree, one can interpret the characteristics in terms of species composition and environmental characteristics that describe the transects that are grouped at each terminal leaf. The barplots at each leaf show the relative covers of the species included in the split. Colors refer to groups represented in an associated PCA that further display in a multidimensional space the relationships among species and similarities among transects. The analysis was completed by looking for indicator species using the index *IndVal* (Dufrêne and Legendre 1997). The index is based on within-species abundance and occurrence comparisons, and tested with randomization procedures (Legendre and Legendre 2012). Its value is maximal (i.e. 1) when the species is observed at all the transects belonging to the same group. A table was built to summarize the information expressed by the MRT, PCA and indicator species analyses.

All analyses were performed in the R software language (version 3.1.2).

4.8.2 Polygon Data

Most analyses, tables, and figures applied on the polygon data were similar to those performed in 2012 (Hawkes et al. 2013), except that again, four years (2007, 2010, 2012, and 2014) of data were included.

One additional analysis, the Kappa statistic (Sim and Wright 2005), was performed to assess further the changes in frequency of polygons mapped in each vegetation community between 2007 and 2014. The Kappa tests assessed whether the number of times that a polygon had the same vegetation community in 2007 and 2014 was different than that expected from chance alone. The kappa statistic is defined as:

$$\frac{\text{proportion of observed agreement - proportion of chance agreement}}{\text{1-proportion of chance agreement}}$$

A value of 1 indicates perfect agreement in a vegetation community between 2007 and 2014, i.e., that each polygon had the same community in the two years. A value of 0 meant that the agreement between the two years was not different than that expected by chance alone. Negative kappa values are possible but rare, and would indicate less agreement than expected by chance alone. The magnitude of the positive kappa statistic indicates the degree of agreement between the two years; values between 0.61 and 0.80 suggest substantial agreement, while values above 0.80 suggested almost perfect agreement (Landis and Koch 1977). The kappa (K) statistics were statistically tested, and confidence intervals computed.

The null hypothesis assumed that K=0. Therefore, significant results meant the K statistics were statistically different than 0, thus the agreement in vegetation communities between 2007 and 2014 was not due to chance alone.

4.8.3 Climatic Data

Meteorological 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: Meteorological stations accessed for weather data in 2014.

Reservoir	Station Name	Latitude	Longitude	Elevation (m)
Kinbasket	Howard	386972	5803720	838
Kinbasket	Valemount Hub	345255	5860266	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, 2012, and 2014).

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

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. Growing degree days (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

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

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 65 in 2012 to 98 in 2012 (Figure 5-1A). In 2014, a total of 98 transects were sampled. The number of times that a given transect was sampled ranges from one to four. All but three of these transects were also sampled in a previous year (2007, 2010, or 2012). Overall, 11 transects have been sampled in all five years; 18 in four of the five years, 46 in three of the five years, and 25 in two of the five years (Figure 5-1B).

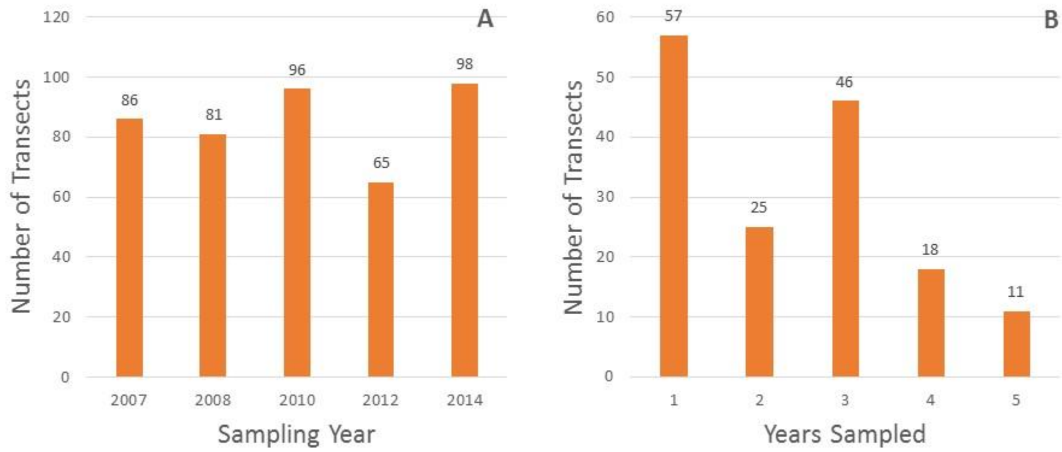


Figure 5-1: Number of transects sampled in the drawdown zone of Kinbasket Reservoir per year (A) and over consecutive years (B).

5.1.1 Vegetation Community Classification

Principal Components Analysis (PCA) in 2014 was moderately successful at grouping species in ordination space in a way that aligned with the 2007 and 2012 community classification (Figure 5-2), lending mixed support to the original classification. For example, the Swamp Horsetails community (SH) appears close in ordination space to Marsh Horsetail (EQUIPAL), *Carex* species and to several other marsh wetland associates (e.g., Yellow Monkey Flower [MIMUGUT], *Equisetum* species). 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). Several communities were associated with one of their dominant or primary species (e.g., BR, RC, CO, BS), and a couple of communities (e.g. CH) were not closely associated in space with their main species. Several communities (e.g., RD, CO, CT, WD, DR) 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 reservoir surcharge, which occurred in 2012 and 2013.

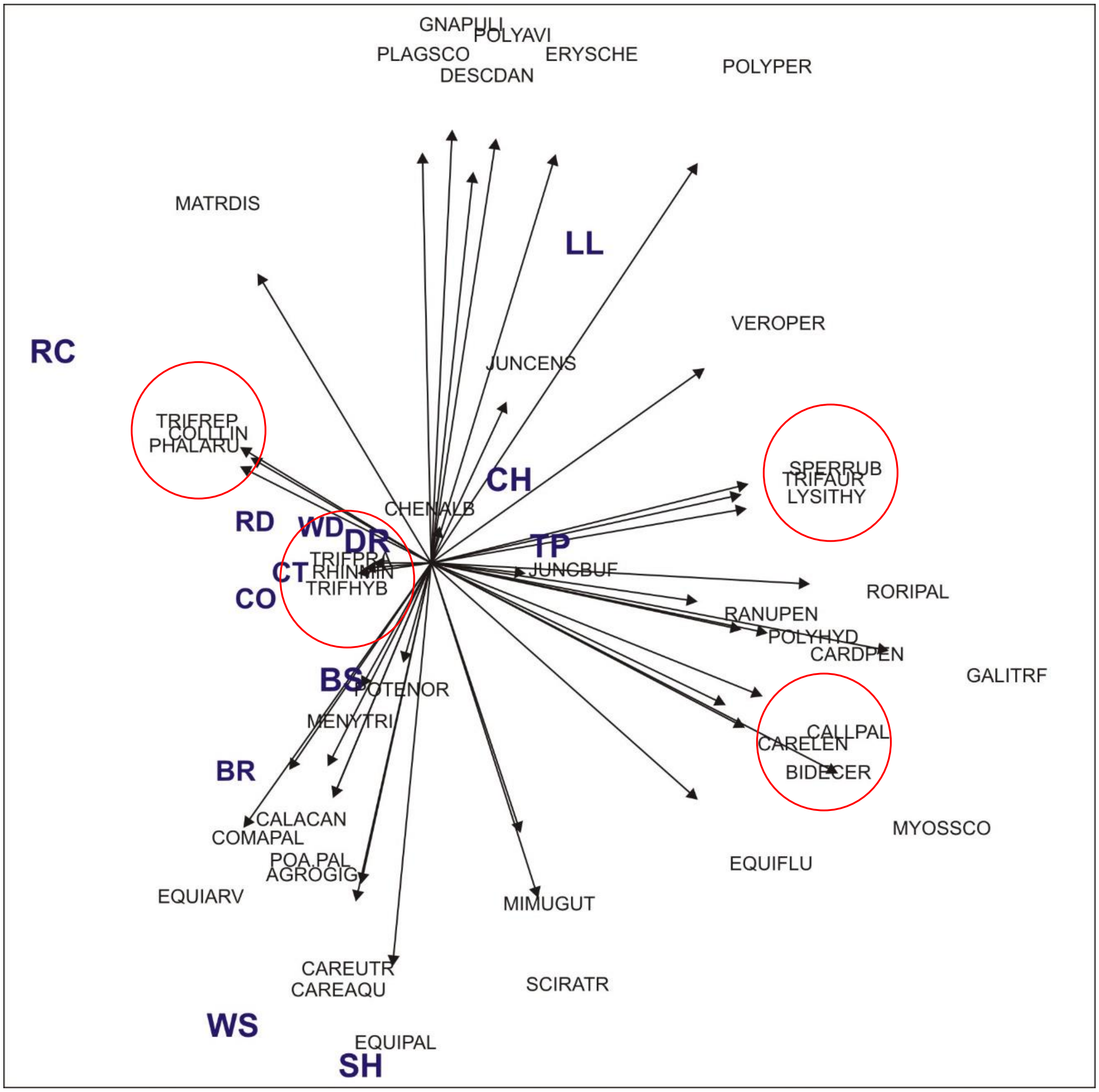


Figure 5-2: PCA diagram correlating the average per cent cover of the main species of vegetation associated with each vegetation community. Axis 1 explains 17 per cent and Axis 2, 16 per cent of the variation in species cover. Community codes (in black) are expanded in Table 4-1**.**

5.1.2 Species Constancy within Vegetation Communities

Since 2007, 291 species of vegetation have been recorded in the drawdown zone of Kinbasket Reservoir; however, excluding 2008, there were 271 species recorded in 2007, 2010, 2012 and 2014[5]. Of those species, 64 (24% of all species seen) were observed in all four years; 51 (19%) were observed in three out of four years; 63 (23%) in two of the four years; and 93 species (34%) were unique to single year (Figure 5-3). We documented a total of 200, 188, 111, and 129 plant species in 2007, 2010, 2012, and 2014 respectively. Differences in total numbers

[5] Data from 2008 are not used in most summaries and analyses because of the reduced total area mapped (aerial photos were acquired later in the year, hence only a portion of the DDZ was photographed0.

of plants per year can be partly attributed to reservoir elevations, especially in 2012 and 2014. Other differences are likely related to reservoir operations (see Hawkes *et al.* 2010). Of the number of species found in each given year, the number of unique species was relatively consistent across the years. 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.

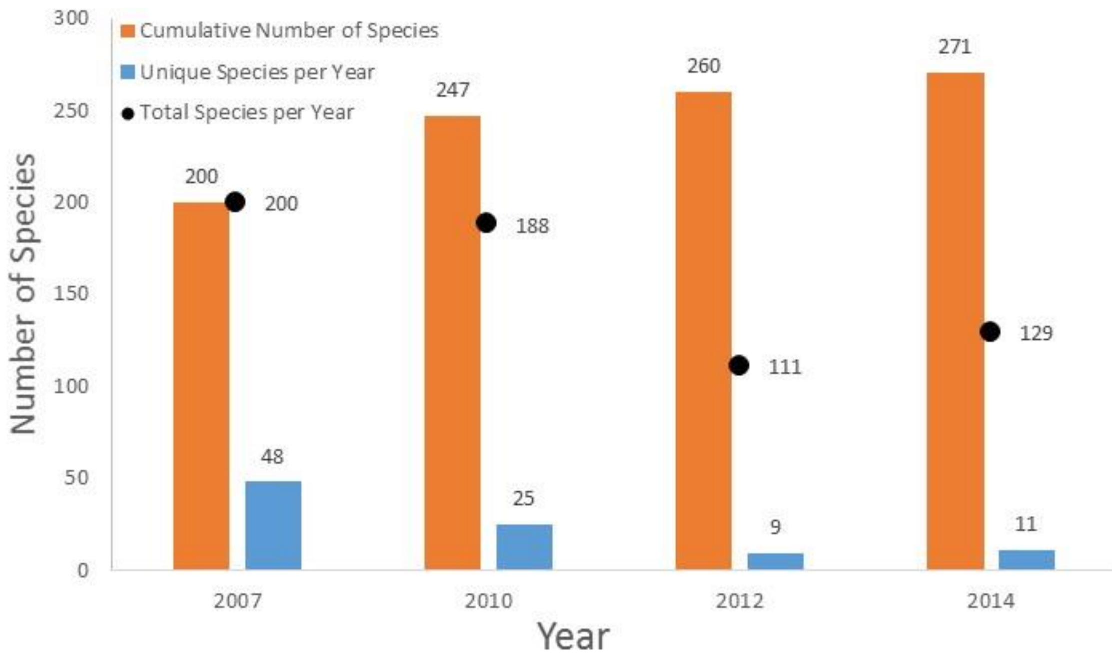


Figure 5-3: The cumulative number of vegetation species detected in the drawdown zone of Kinbasket Reservoir since 2007. The number of unique species and total number of species detected per year of sampling are also shown.

Species constancy averaged 49% (SD = 29%) over the four years. Species constancy was assessed for each transect sampled in all four years (2007, 2010, 2012, and 2014) (n = 16; Table 5-1). The constancy of species varied from 0 per cent at transect 76, where none of the species seen in 2014 were found in previous years, to nearly 100% in transects 56 and 63. In transects 56 and 63 only one species recorded previously was also documented in 2014: Common Horsetail (EQUIARV). It is also worth noting that most species seen in transects 56 and 63 were common between 2007 and 2010, but not in later years. The same trend was also noted for overall richness; richness being two to three times lower in transect 63 to over ten times lower in transect 56 between 2007/2010 and 2012/2014.

Table 5-1: Species constancy on transects sampled over time in Kinbasket Reservoir (2007, 2010, 2012, and 2014). Per cent constancy is calculated as the proportion of all species present in 2014 that were recorded in all four years of sampling. Landscape units are ordered from south to north in Kinbasket Reservoir.

Landscape Unit	Transect	Number of species observed in...									
		2007 only	2010 only	2012 only	2014 only	2/4 years	3/4 years	all 4 years	Total in 2014	Total (overall)	% constancy
Bush Arm	29	3	2	0	0	3	1	6	8	15	75
Bush Arm	30	6	1	4	1	2	8	9	16	31	56
Bush Arm	33	6	1	1	2	7	4	7	15	28	47
Bush Arm	76	8	2	2	1	3	7	0	8	23	0
Bush Arm	79	5	2	4	1	4	2	3	8	21	38
Sullivan Arm	56	11	5	0	0	15	2	1	1	34	100
Sullivan Arm	58	1	4	0	0	3	0	1	2	9	50
Encampment Ck	21	9	0	1	6	5	2	4	16	27	25
Encampment Ck	25	5	1	1	1	4	7	10	18	29	56
Grouse Ck	62	14	8	0	1	9	2	3	7	37	43
Grouse Ck	63	12	3	0	0	2	0	1	1	18	100
Mt. Blackman	18	1	0	0	2	2	2	1	6	8	17
Ptarmigan Ck	60	6	4	0	6	7	5	5	18	33	28
Canoe Reach	6	0	3	6	1	3	4	4	8	21	50
Canoe Reach	8	1	1	4	1	1	3	4	5	15	80
Canoe Reach	9	3	1	0	1	5	3	1	6	14	17

Overall, species constancy did vary by elevation (Figure 5-4). In 2010, there was a strong negative relationship between species constancy (previously termed "persistence"; Hawkes *et al.* 2010) and elevation that was not observed in 2012 (Hawkes et al. 2013) or 2014 ($p > 0.05$).

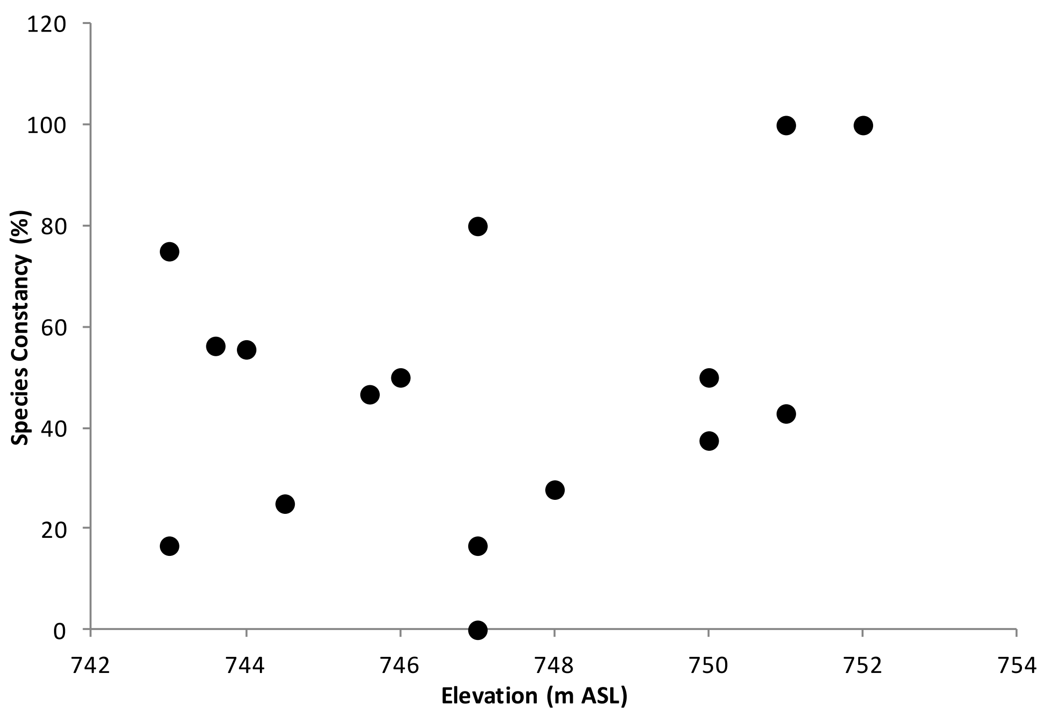


Figure 5-4: Plant species constancy (%) in resampled transect (*n* = 16) over the four years of sampling, in relation to elevation (m ASL). The relationship was not statistically significant ($p > 0.05$).

Species constancy varied among communities between 2007 and 2014 (Table 5-2; Figure 5-5). The Toad Rush-Pond Water Starwort (TP) community had the highest proportion of stable species recorded in the four years of sampling, followed by Lady's Thumb-Lamb's Quarter (LL) community (Figure 5-5). High species constancy in these communities is likely related to several factors including elevation (lower elevation) and topography (generally flatter sites). Consequently, the species likely to be found there are ones that can withstand a substantial amount of inundation. Species constancy was most variable in the Clover-Oxeye Daisy (CO) and Bluejoint Reedgrass (BR) communities. Average constancy of species was rather low over time (36 per cent, SD = 17 per cent), indicating the variable nature of vegetation communities in the reservoir. The two communities that had the highest number of species overall (CO and Willow-Sedge Wetland [WS]) also had among the lowest percentage of constant species; most of the species were recorded in 2007 and 2010. The BR, Swamp Horsetails (SH), WS, and Cottonwood-Trifolium (CT) communities had between 20 and 25 per cent of their species recorded for the first time in 2014 (i.e., were "unique").

Table 5-2: Species constancy within vegetation communities sampled in 2007, 2010, 2012, and 2014. Note: different numbers of transects were sampled per community in each year. Per cent constancy calculated as the proportion of all species present in 2014 that were recorded in all four years. Communities were ordered according to seral stage, from pioneering to late seral. Refer to Table 4-1 for vegetation community definitions.

Vegetation communities	Number of species observed in…							Total in 2014	Total (overall)	% constancy
	2007 only	2010 only	2012 only	2014 only	2/4 years	3/4 years	all 4 years			
LL	10	10	1	4	11	5	17	27	58	63
CH	5	35	1	7	17	14	14	48	93	29
TP	6	3	1	1	4	4	16	21	35	76
MA	10	1	2	2	8	6	9	20	38	45
KS	15	8	6	4	25	18	21	54	97	39
BR	18	13	3	7	23	8	6	30	78	20
CO	57	18	1	7	47	24	7	49	161	14
WB	2	6	7	3	7	19	11	35	55	31
SH	23	7	0	4	11	10	7	21	62	33
BS	9	1	7	0	6	11	3	12	37	25
WS	22	17	2	9	30	17	11	48	108	23
CT	11	15	19	5	15	9	6	23	80	26
LH	13	3	--	--	--	--	2*	--	18	--
DR	--	2	12	2	4	--	3**	8	23	38

* sampled in only two years; ** sampled in only three years

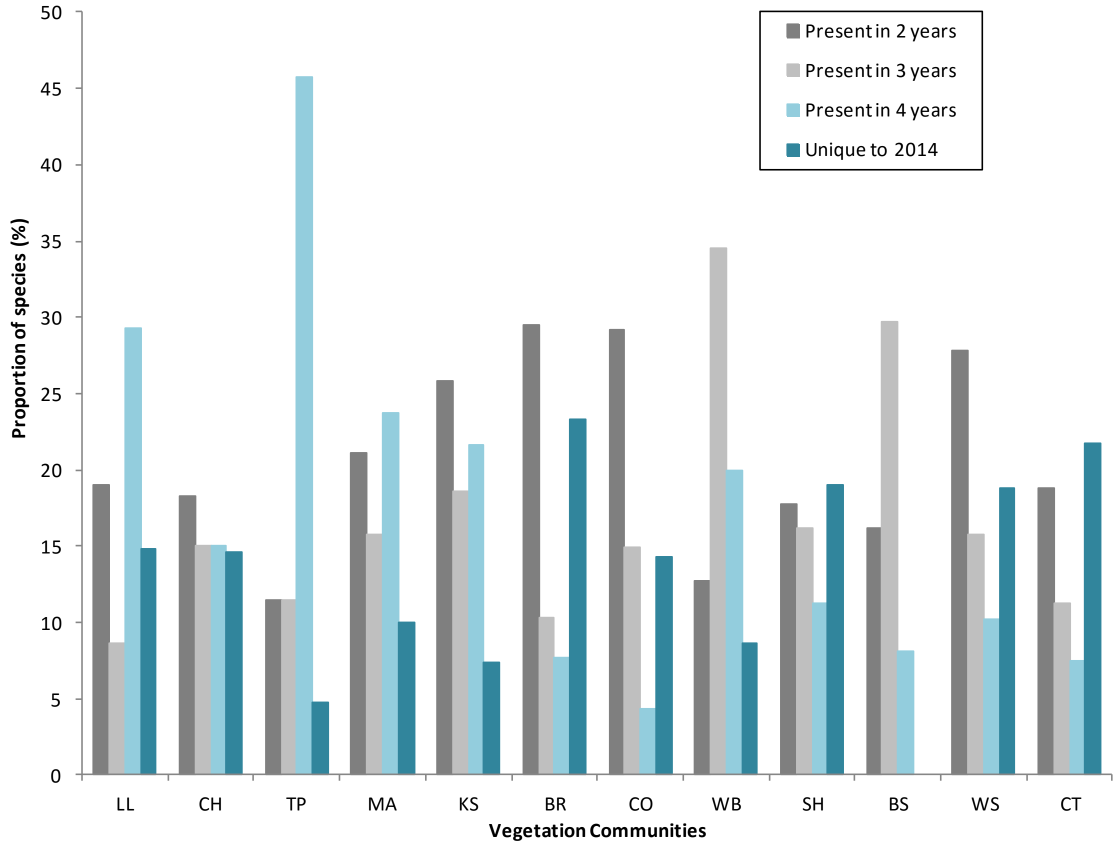


Figure 5-5: Proportion of species that were present in two, three, or four years of sampling (encompassing 2007, 2010, 2012, and 2014), and proportion of species unique to 2014. Vegetation communities were ordered per seral stage, from pioneering to late seral communities. Refer to Table 4-1 for a description of the vegetation communities.

Over time, the number of unique species has decreased for most communities: there were more unique species in 2007 than in subsequent years, even when the number of species was corrected by the number of transects. Despite some variation, communities in 2012 and 2014 appear more similar (with the exception of SH, BS, CT) than in 2007 and 2010. The largest number of unique species (i.e., sampled in only one community in 2014) was associated with the Willow-Sedge Wetland (WS) community followed by the Bluejoint Reedgrass (BR) and the Cottonwood-Trifolium (CT) communities (Figure 5-6). The lowest number of unique species was associated with the Buckbean-Slender Sedge (BS) community, with no unique species. 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.

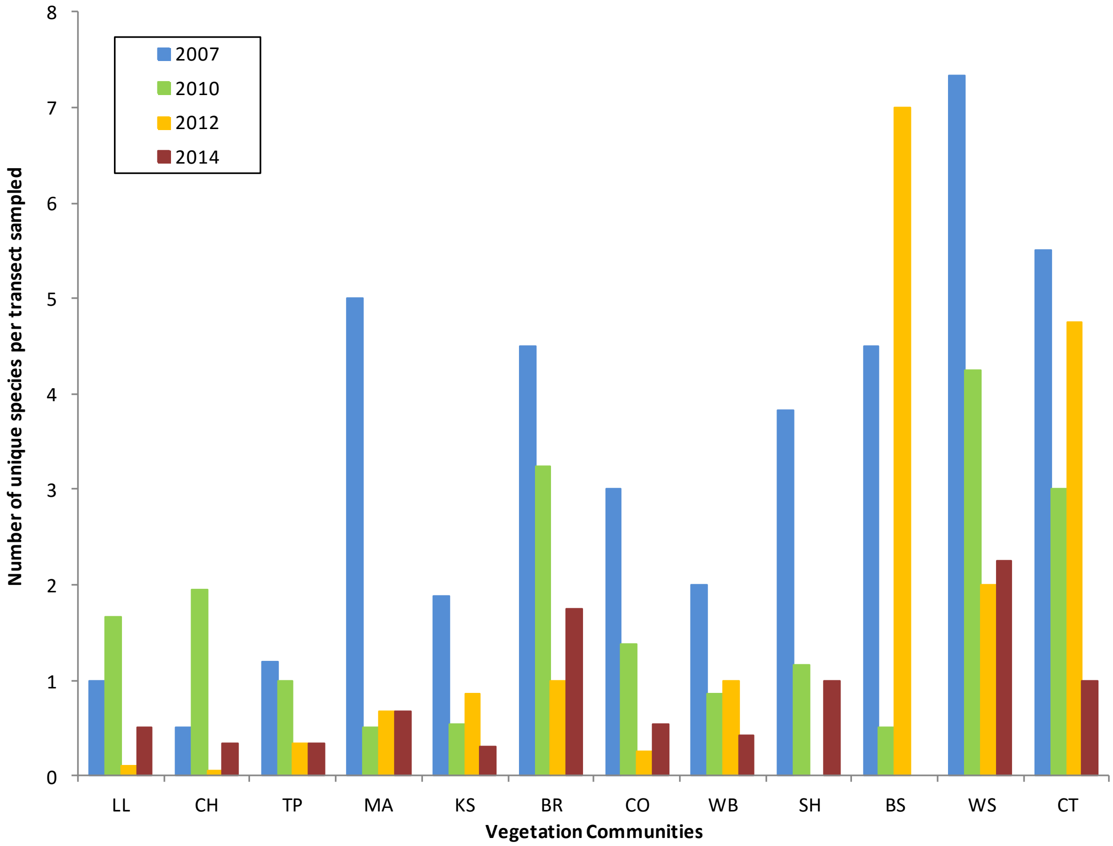


Figure 5-6: Number of species unique to a vegetation community over time, corrected for the number of transects sampled each year. Vegetation communities were ordered according to seral stage, from pioneering to late seral communities. Refer to Table 4-1 for vegetation community codes.

Over 50 species in each year were recorded in only one vegetation community, for all years of sampling. Only very few species were generalists, and observed in more than one or two vegetation communities (Figure 5-7). The generalist species, observed in almost all vegetation communities were: Common Horsetail (*Equisetum arvense*) and Kellogg's Sedge (*Carex lenticularis* ssp. *lipocarpa*). However, Bluejoint Reedgrass (CALACAN), Norwegian Cinquefoil (POTENOR), White clover (TRIFREP), Grass sp. (POA), Lady's-thumb (POLYPER), and European Forget-me-not (MYOSSCO) were also frequently encountered. 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.

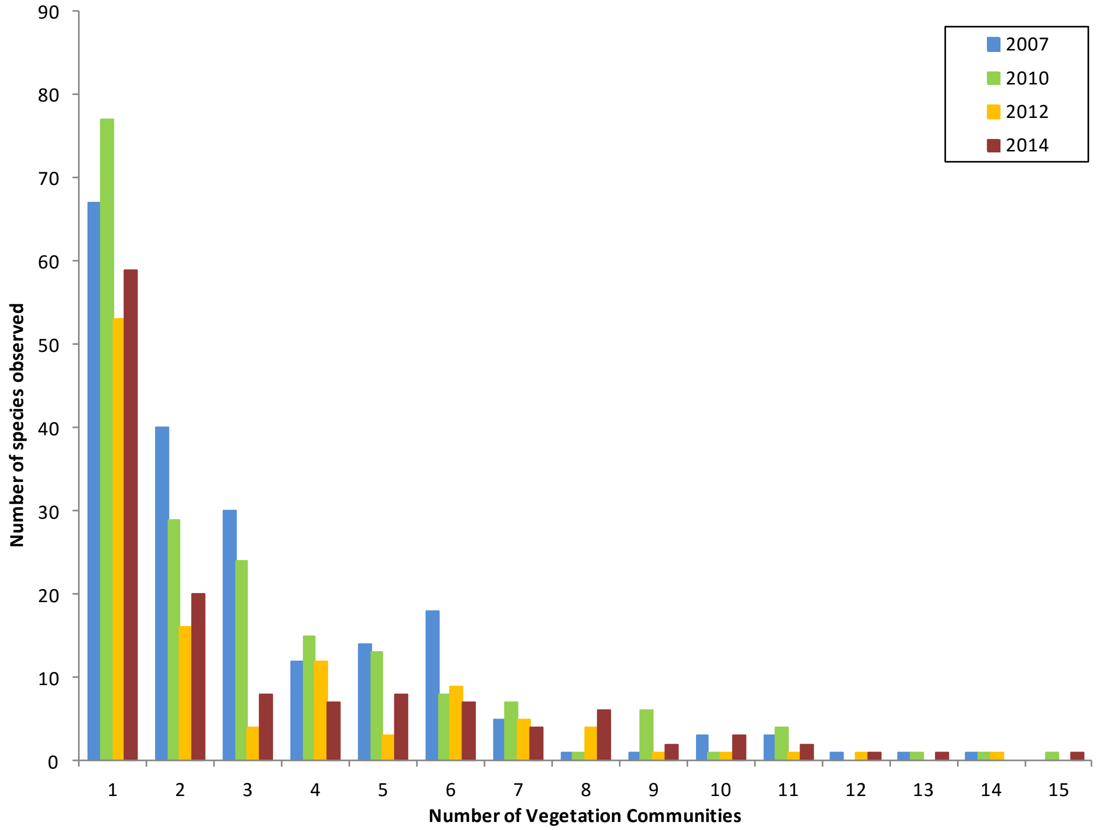


Figure 5-7: Number of vegetation communities in which a given species was observed in 2007, 2010, 2012, and 2014. A high proportion of observations were limited to one or two community types (i.e., specialized), whereas only a few species were sampled in eight different communities or more (i.e., generalists).

5.1.3 Species Richness, Diversity, and Evenness of Vegetation Communities

Total species richness varied among vegetation communities and over time (Figure 5-8). With the exception of a few outlying points, the total number of species per VCC (corrected by the number of transects sampled) appeared to be relatively similar across most years, especially between 2012 and 2014. The notable outliers include high richness values in 2007, especially in Marsh Cudweed-Annual Hairgrass (MA) and Wool-grass-Pennsylvania Buttercup (WB) communities, and in 2012, in Buckbean-Slender Sedge (BS) and Willow-Sedge Wetland (WS). Most vegetation communities had between five to ten species, with total species richness seemingly peaking in the mid-seral (Table 4-2) and wetland-associated communities (BS and Willow-Sedge Wetland [WS]) rather than in the early and late seral communities.

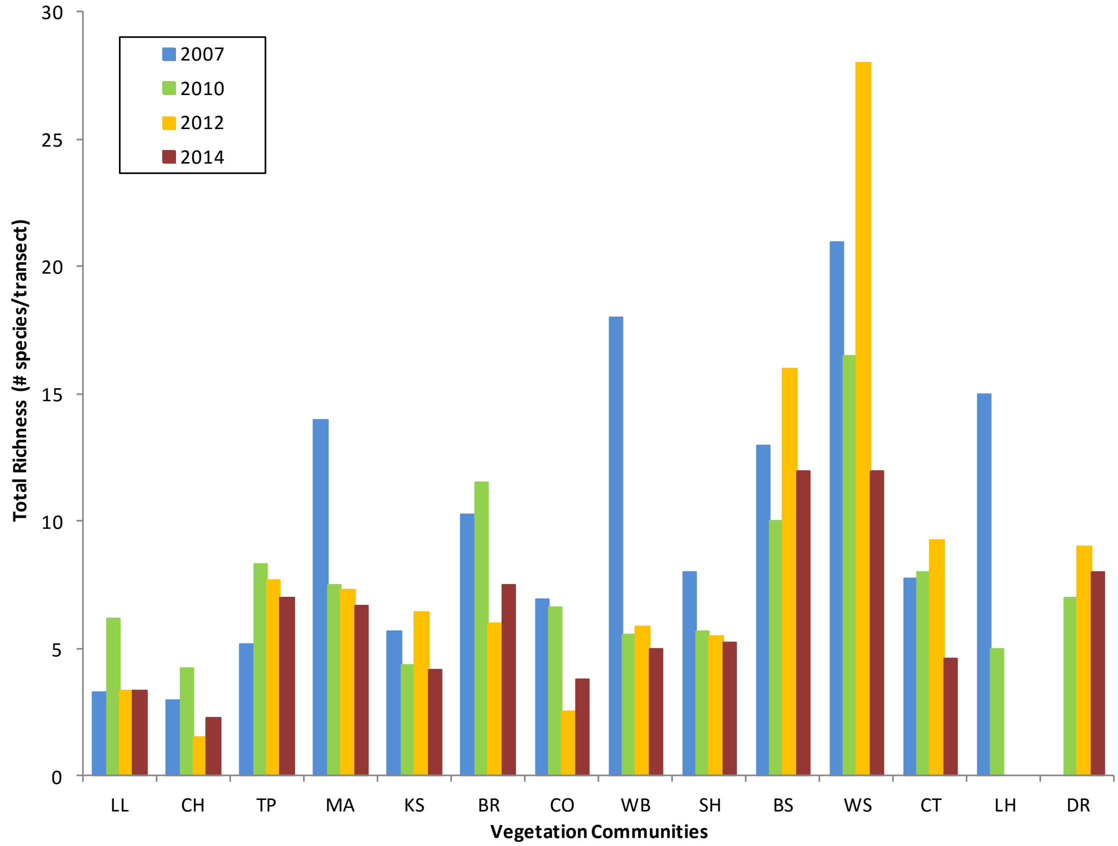


Figure 5-8: Total richness (number of species) per vegetation community in 2007, 2010, 2012, and 2014, corrected by the number of transects sampled in each year. Vegetation communities are ordered relative to seral stage, from pioneering to late seral communities. Refer to Table 4-1 for a description of the vegetation communities.

Species richness varied significantly among vegetation communities and across time within some (but not all) communities (Figure 5-9). Differences in species richness were statistically significant among years (F=5.9, p=0.00001) and vegetation communities (F=9.6, p=0.00002). Interactions were also significant (F=2.2, p=0.001); there were significant differences among vegetation communities in all years (one-way ANOVAs -2007: F=24.8, p=0.0001; 2010: F=3.7, p=0.001; 2012: F=3.7, p=0.002; 2014: F=2.5, p=0.02) and among years for CO (F=30.6, p=0.0001), MA (F=18.3, p=0.004), and KS (F=4.6, p=0.006) communities. Differences in richness in WB, BS, WS and DR were not tested due to a lack of replicates in one or more years.

Overall, the Willow-Sedge Wetland (WS) and Cottonwood-Trifolium (CT) communities showed the highest richness relative to the other communities. Richness was lowest in 2014 in Lady's thumb-Lamb's Quarter (LL), Marsh Cudweed-Annual Hairgrass (MA), and Common Horsetail (CH) communities, and appeared generally less variable among transects than in other years (i.e., shorter boxes) and had consistently low species richness. Although not tested statistically because of a lack of replicated sampling in 2012, richness was much lower in 2014 in the (WS) community than in earlier years. Richness per transect was highly variable over time for Marsh Cudweed-Annual Hairgrass (MA), possibly consistent with it being an annual-dominated, ruderal community. Lack of replicates in one or more years precluded comparing richness across years for certain communities (e.g., Wood-grass-Pennsylvania Buttercup (WB), Buckbean-Slender Sedge (BS), WS).

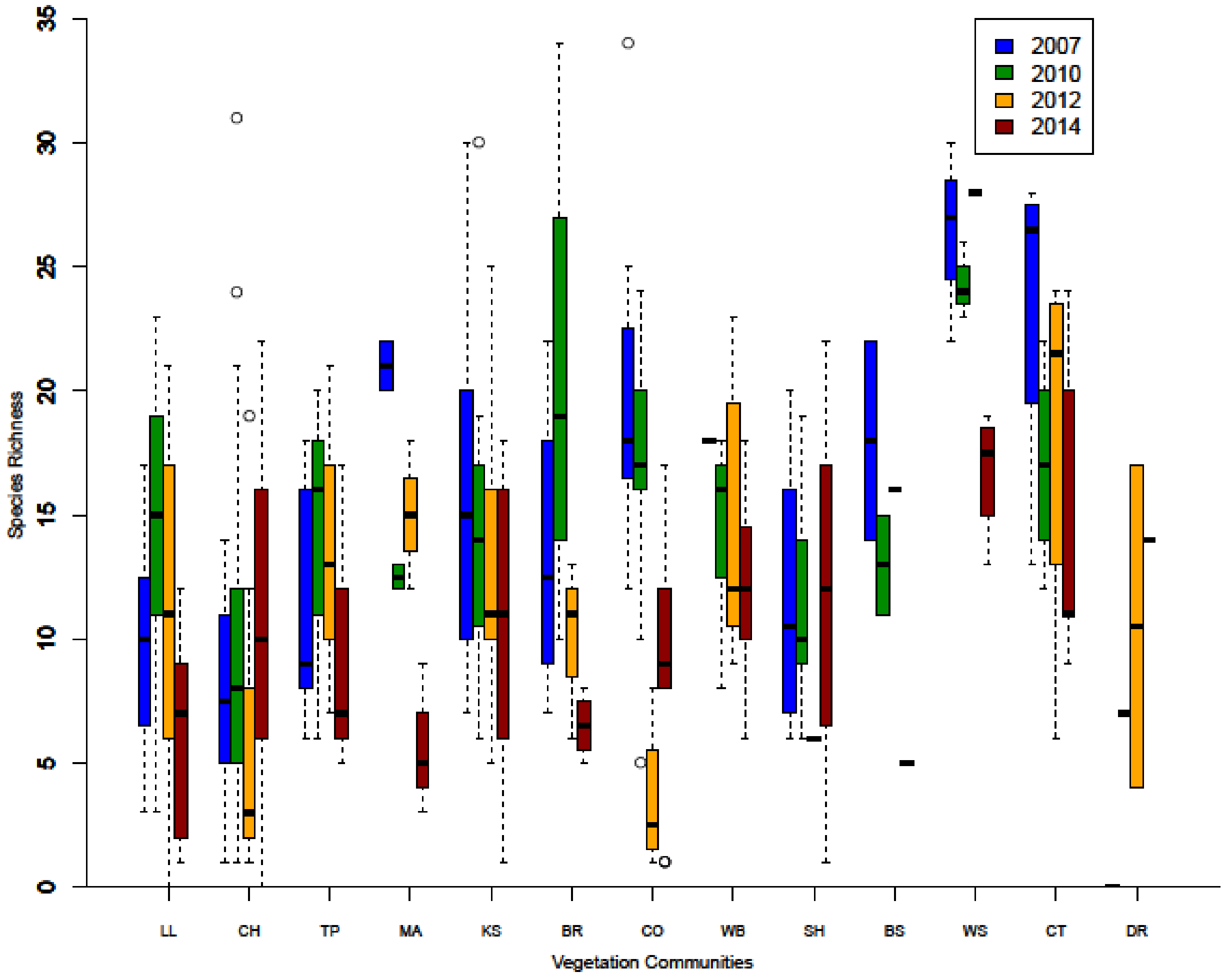


Figure 5-9: Variation in species richness per transect over time, per vegetation community. Vegetation communities were ordered per seral stage, from pioneering to late seral communities. Refer to Table 4-1 for a description of the vegetation communities.

Diversity also varied significantly among vegetation communities and years, and appeared consistently lower in 2014 than in previous years, especially for Lady's thumb-Lamb's Quarter (LL), Toad Rush-Pond Water-starwort (TP), Marsh Cudweed-Annual Hairgrass (MA), Wool-grass-Pennsylvania Buttercup (WB), Buckbean-Slender Sedge (BS), and Cottonwood-Trifolium (CT) communities (Figure 5-10). Differences in species diversity were statistically significant among years ($F=2.7$, $p=0.0065$) and vegetation communities ($F=12.8$, $p=0.00001$). Interactions were significant ($F=2$, $p=0.004$); one-way ANOVAs found significant differences among vegetation communities only in 2007 ($F=18$, $p=0.0001$), and among years for MA ($F=10.4$, $p=0.0001$), KS ($F=3.4$, $p=0.03$), CO ($F=31$, $p=0.0001$), and CT ($F=11.1$, $p=0.0006$) communities. Differences in diversity in WB, BS, WS and DR communities were not tested because of lack of replicates in one or more years.

Diversity seemed to increase slightly in 2014 compared to 2012 in the Clover-Oxeye Daisy (CO) community, although both years show much smaller values than in 2007 and 2010.

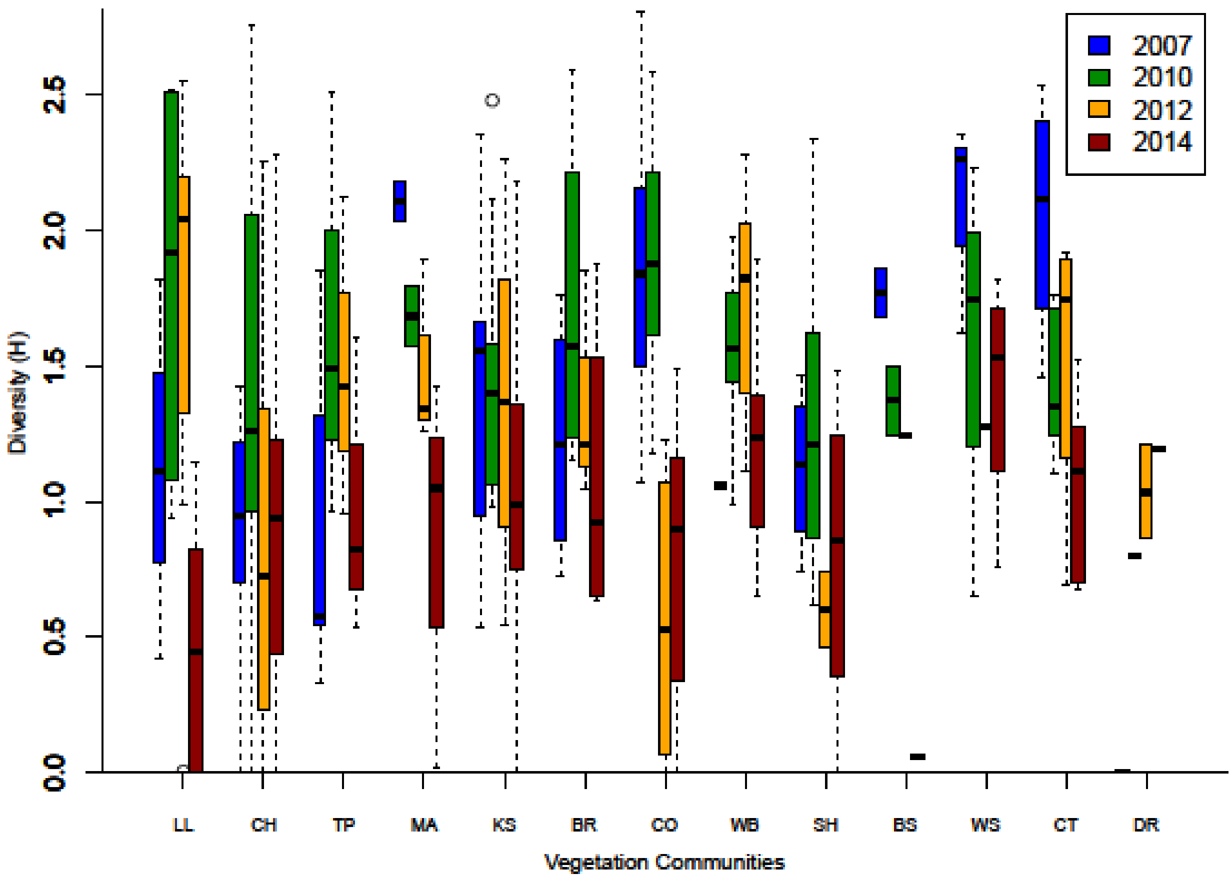


Figure 5-10: Variation in species diversity (Shannon's H) per transect over time, per vegetation community. Vegetation communities were ordered per seral stage, from pioneering to late seral communities. Refer to Table 4-1 for a description of the vegetation communities.

Evenness in the distribution of species was more variable among transects in 2014 than for richness or diversity, but showed similar trends with evenness being generally lower in 2014 than in previous years (Figure 5-11). Differences in evenness were significant among years only (F=7.9, p=0.00005). That was especially the case for LL, WB and CT communities, while evenness in MA, CH, CO, and Swamp Horsetails (SH) communities varied greatly among transects sampled in 2014. Differences in evenness were statistically significant among years (F=7.9, p=0.00005), but not among communities (p>0.05).

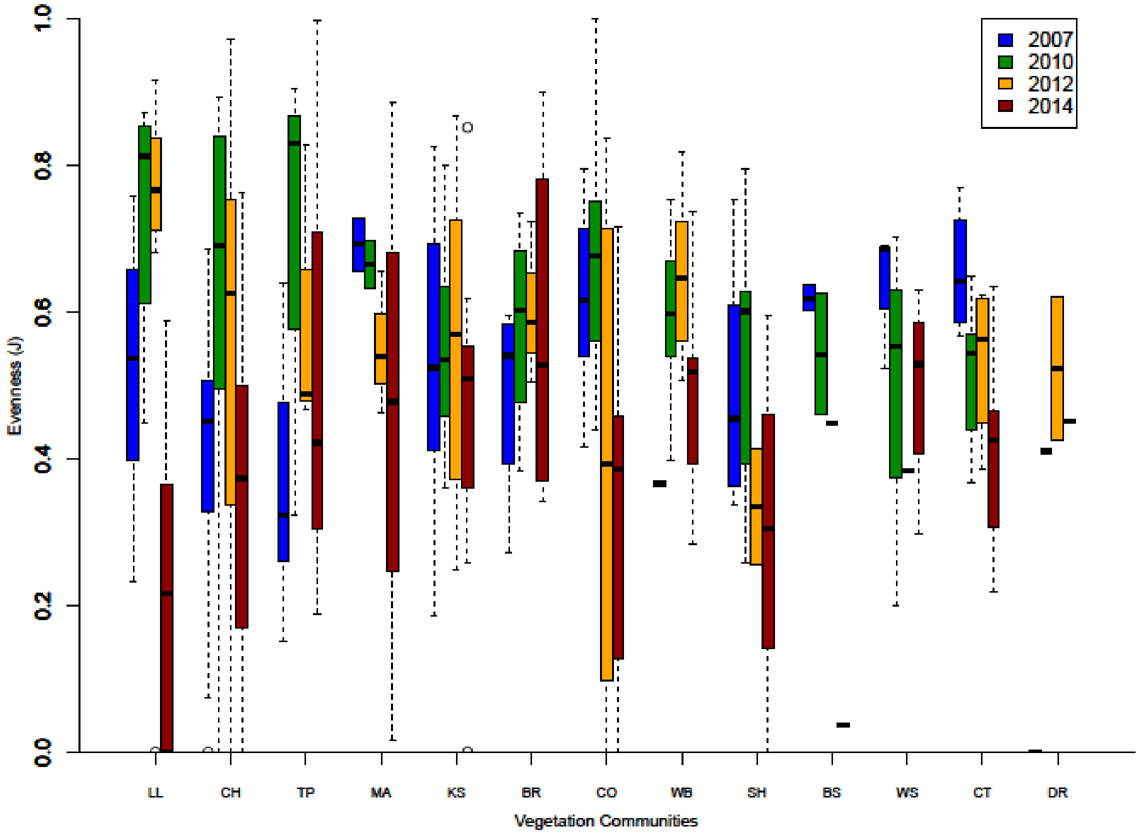


Figure 5-11: Evenness (J) of the distribution of species per transect over time, per vegetation communities. Vegetation communities were ordered per seral stage, from pioneering to late seral communities. Refer to Table 4-1 for a description of the vegetation communities.

5.1.4 Species Richness, Diversity, and Evenness and Landscape Units

Most unique species by landscape unit (i.e., species observed in only one year by site) were recorded in Bush Arm, followed by Encampment Creek and Canoe Reach (Figure 5-12). Most of the unique species across the landscape units were documented in 2007 and 2010. Bush Arm, Encampment Creek, and Canoe Reach also had the highest number of new species recorded, with 2007 having the largest numbers because it was the first year of study (Figure 5-13). Most of the new species recorded in 2014 were in Yellow Jacket Creek and Bush Arm, despite similar sampling effort as in previous years (i.e., similar number of transects sampled). In comparison, the sampling effort in Sprague Bay was doubled in 2014 compared to previous years, but the number of new species recorded did not increase.

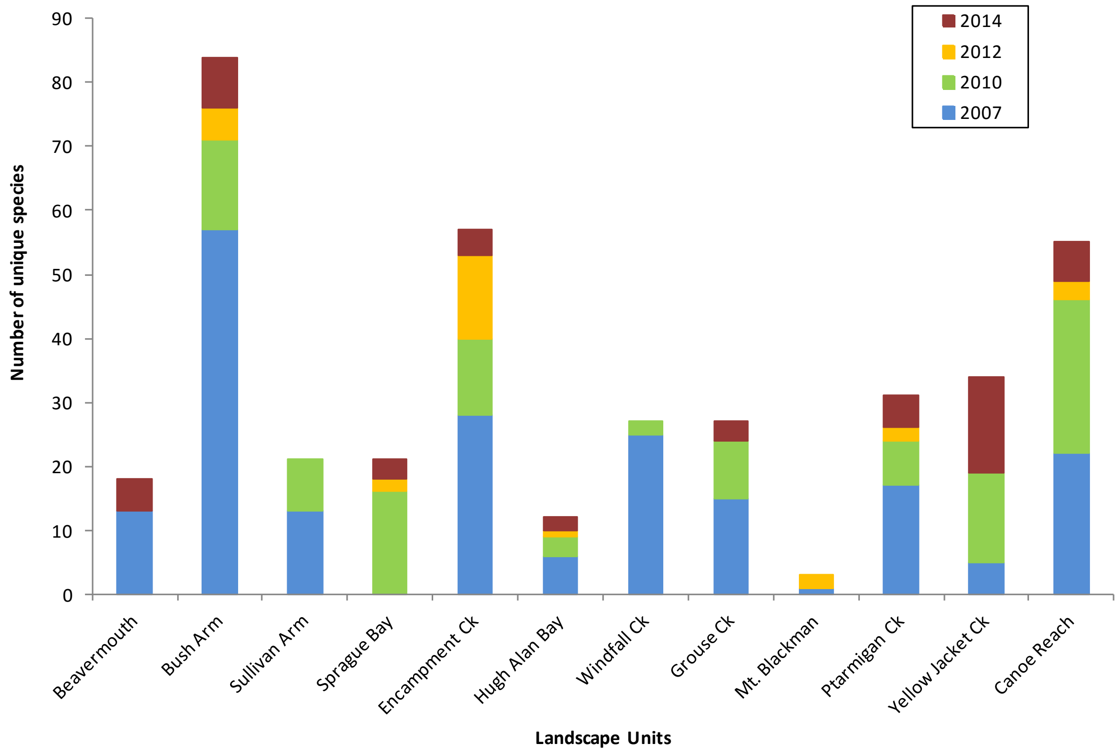


Figure 5-12: Number of unique species recorded in each landscape unit over time (2007, 2010, 2012, and 2014). Some data are not shown for certain years: Howard Creek was sampled only in 2007, Sprague Bay was not sampled in 2007, and Beavermouth was not sampled in 2012. Landscape units are ordered from south to north in Kinbasket Reservoir.

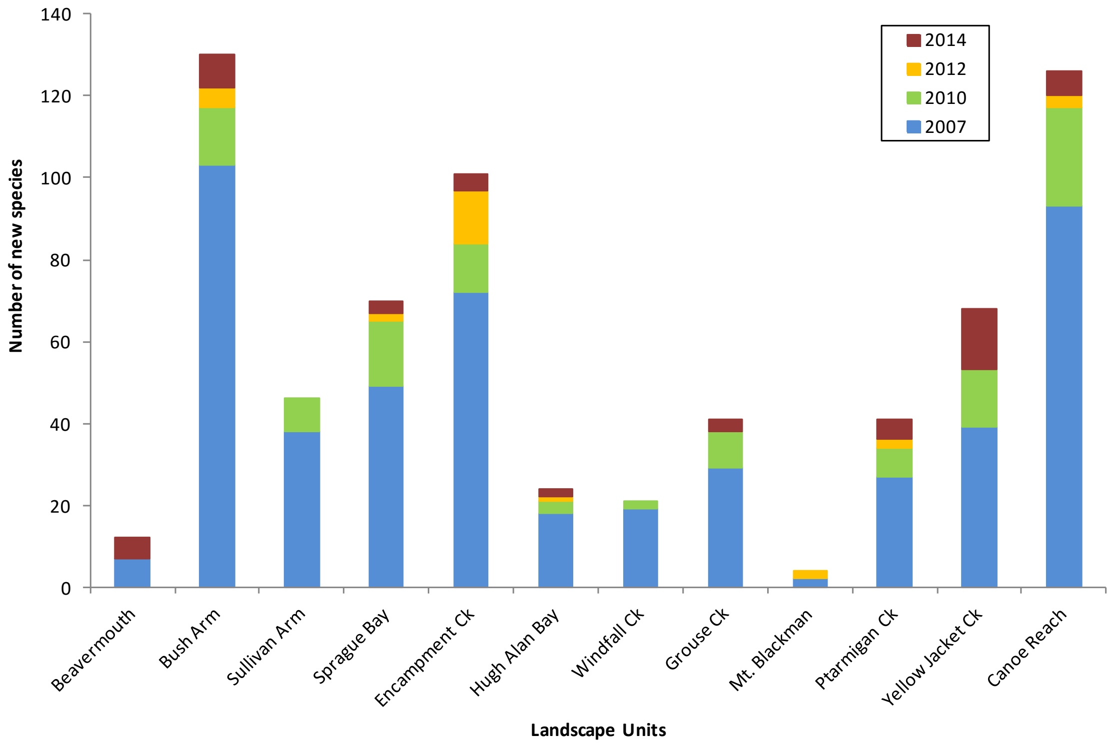


Figure 5-13: Number of new species recorded in each landscape unit over time (2007, 2010, 2012, and 2014). Howard Creek was sampled only in 2007, Sprague Bay was not sampled in 2007, and Beavermouth was not sampled in 2012. Landscape units are ordered from south to north in Kinbasket Reservoir.

A comparison of the overall species richness in each landscape unit between 2007 and 2014 suggests that species richness declined in all but two areas (Mt. Blackman and Yellow Jacket Creek; Table 5-3). However, the situation is slightly different when the species richness is corrected by sampling effort (Table 5-3, Figure 5-14); in that case, species richness stayed rather stable over time in Beavermouth, Bush Arm, Encampment Creek, Hugh Alan Bay, Mt. Blackman, and Canoe Reach. In summary, Sullivan Arm, Sprague Bay, Windfall Creek, Grouse Creek, and Ptarmigan Creek showed decline in species richness over time either ways, while species richness at Yellow Jacket Creek declined (corrected by the number of transects sampled).

Table 5-3: Species richness in 2007, 2010, 2012, and 2014, and total number of species recorded over time in each landscape unit. Direction of change corresponds to a qualitative indication of whether the richness increased (+), decreased (-), or stayed stable over time (=); "corrected" means the comparison of richness was based on richness corrected by the number of transects sampled in that landscape unit that year. Landscape units are ordered from south to north in Kinbasket Reservoir.

Lanscape Unit	Species Richness				Total	Direction of change	
	2007	2010	2012	2014		absolute	corrected
Beavermouth	22	7	--	10	28	-	=
Bush Arm	149	103	72	83	192	-	=
Sullivan Arm	49	38	35	--	48	-	-
Sprague Bay	--	49	38	35	60	-	-
Encampment Ck	84	72	59	50	124	-	=
Hugh Alan Bay	18	18	15	13	31	-	=
Windfall Ck	42	19	2	1	44	-	-
Grouse Ck	31	29	8	1	45	-	-
Mt. Blackman	8	2	8	7	11	=	=
Ptarmigan Ck	40	27	23	24	57	-	-
Yellow Jacket Ck	22	39	2	35	59	=	-
Canoe Reach	80	93	35	56	128	-	=

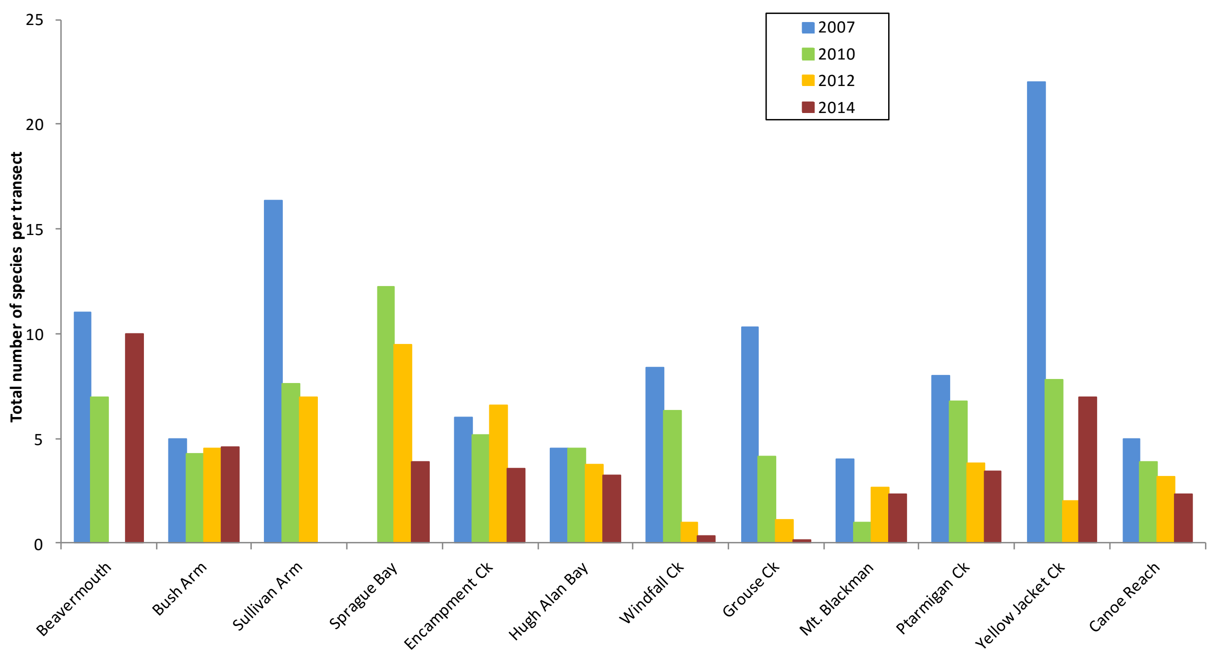


Figure 5-14: Total species richness per transect corrected by sampling effort per landscape unit in 2007, 2010, 2012, and 2014 in Kinbasket Reservoir. Landscape units were ordered from south to north.

In general, species richness has declined over time (Figure 5-15). The total number of species recorded per landscape unit was less variable among transects of each landscape unit in 2014 than in previous years. Differences in species richness were statistically significant among years (F=14.8, p=0.00001), and among landscape units (F=12.6, p=0.00001). Interactions were also significant (F=1.6, p=0.036); one-way ANOVAs found significant differences among landscape units in 2007 (F=12, p=0.0001) and 2014 (F=5.2, p=0.0002), and among years in Bush Arm (F=5.4, p=0.002), Sullivan Arm (F=14.5, p=0.001), Windfall Creek (F=12.2, p=0.003), Grouse Creek (F=9.2, p=0.002), and Canoe Reach (F=4.6, p=0.0045). Differences in richness in Beavermouth, Sprague Bay, and Yellow Jacket Creek were not tested because of lack of replicates in one or more years. Species richness declined markedly over time in Sullivan Arm and Windfall Creek (Figure 5-15). Declines in species richness were significant for Bush Arm, Sullivan Arm, Windfall Creek, Grouse Creek, and Canoe Reach.

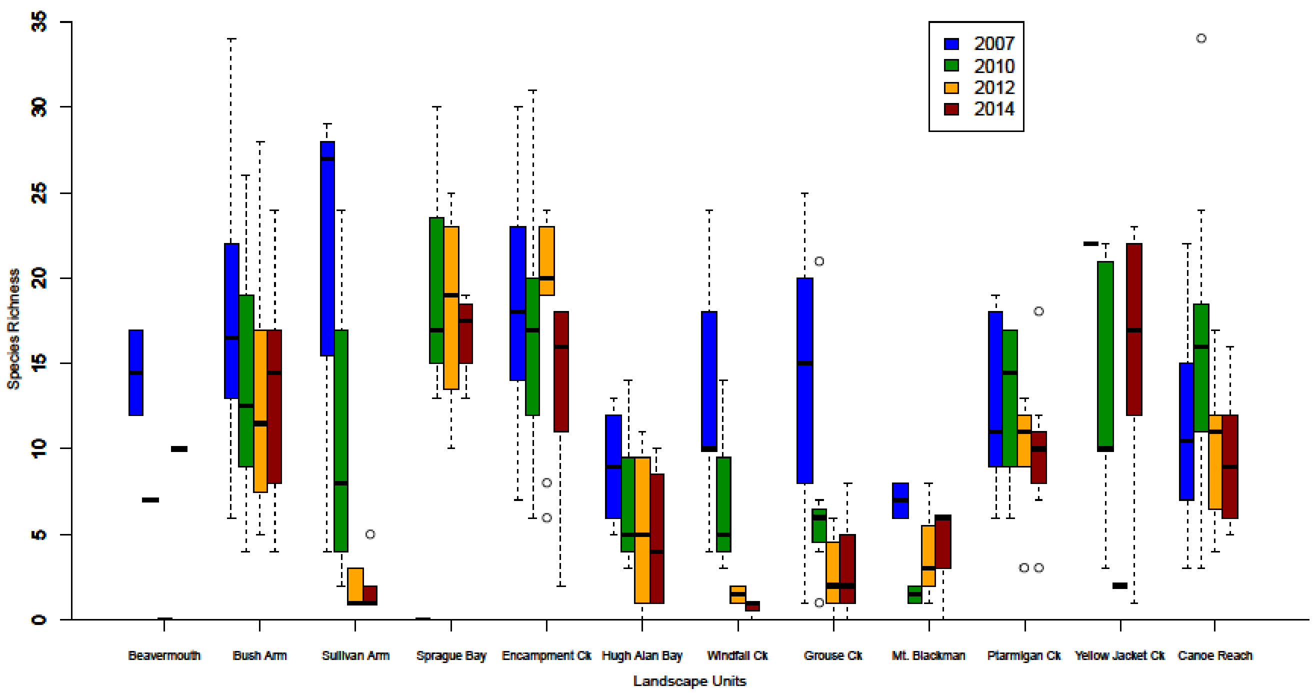


Figure 5-15: Species richness per transect in each landscape unit in 2007, 2010, 2012 and 2014. Landscape units are ordered from south to north in Kinbasket Reservoir.

Species diversity was very low in 2014 in Sullivan Arm, Hugh Alan Bay, Windfall Creek, and Mount Blackman, and generally lower in 2014 than in previous years (Figure 5-16). Differences in species diversity were statistically significant among years (F=9.2, p=0.00001), and among landscape units (F=18.1, p=0.00001). Interactions were also significant (F=2.2, p=0.001); there were significant differences among landscape units in 2007 only (one-way ANOVAs - F=12.5, p=0.0001), and among years in Bush Amr (F=5.8, p=0.001), Sullivan Arm (F=7.8, p=0.005), Encampment Creek (F=3.8, p=0.015), Hugh Alan Bay (F=8.1, p=0.004), Windfall Creek (F=10.05, p=0.005), and Grouse Creek (F=6.8, p=0.003). Differences in diversity in Beavermouth, Sprague Bay, and Yellow Jacket Creek were not tested because of lack of replicates in one or more years. Declines in species diversity over time were also significant in Bush Arm, Sullivan Arm, Encampment Creek, Hugh Alan Bay, Windfall Creek, and Grouse Creek.

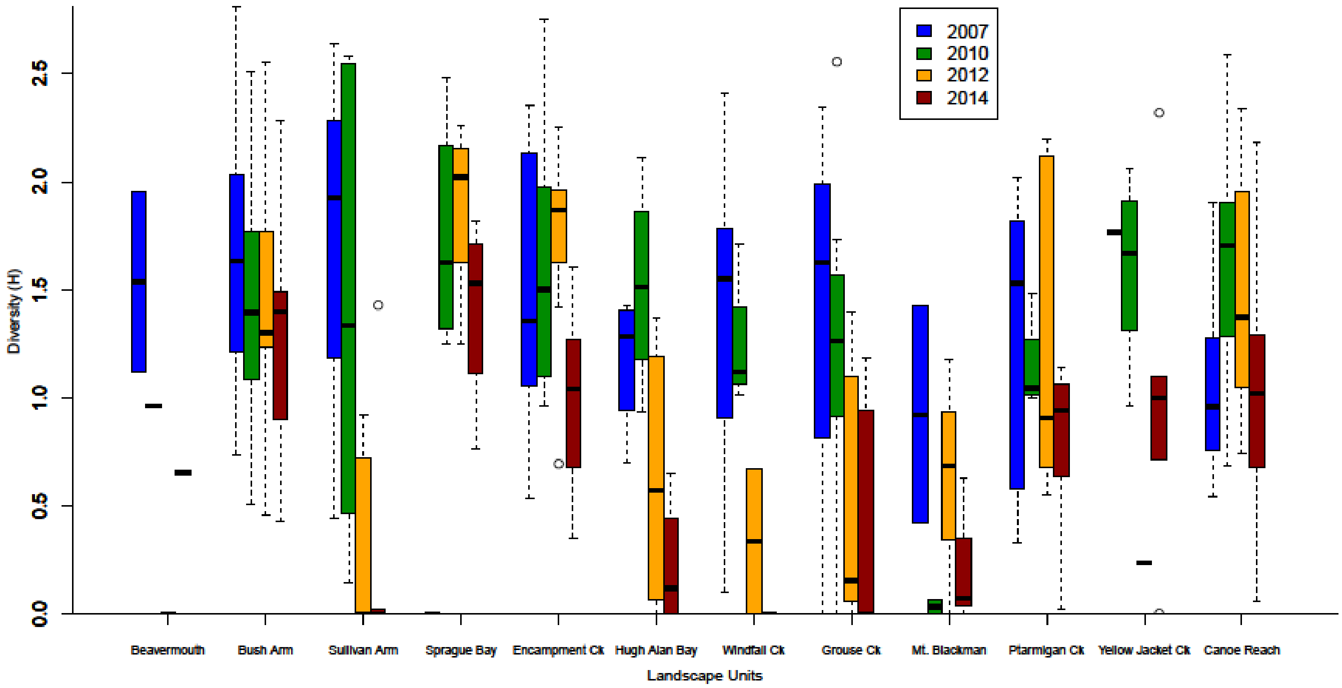


Figure 5-16: Species diversity (Shannon's H) per transect in each landscape unit in 2007, 2010, 2012 and 2014. Landscape units are ordered from south to north.

Individual landscape units had generally quite variable evenness, with overall trends similar to that for diversity. Differences in species evenness were statistically significant among years (F=4.2, p=0.00001), and landscape units (F=20.0, p=0.00001). Interactions were also significant (F=2.5, p=0.0002); one-way ANOVAs found significant differences among landscape units in 2007 (F=6.15, p=0.0001), and among years in Hugh Alan Bay (F=7.5, p=0.006). Differences in evenness in Beavermouth, Sprague Bay, and Yellow Jacket Creek were not tested because of lack of replicates in one or more years. Evenness values were generally lower in 2014 than in previous years, with smaller variation among transects (Figure 5-17). Evenness in distribution of species within landscape units was smaller in 2014 in Beavermouth, Sullivan Arm, Sprague Bay, Encampment Creek, Hugh Alan Bay, Grouse Creek, Mount Blackman, Ptarmigan Creek, Yellow Jacket Creek, and Canoe Reach. That decline in evenness suggests that the communities in those landscape units are more dominated by a few species, and less diverse.

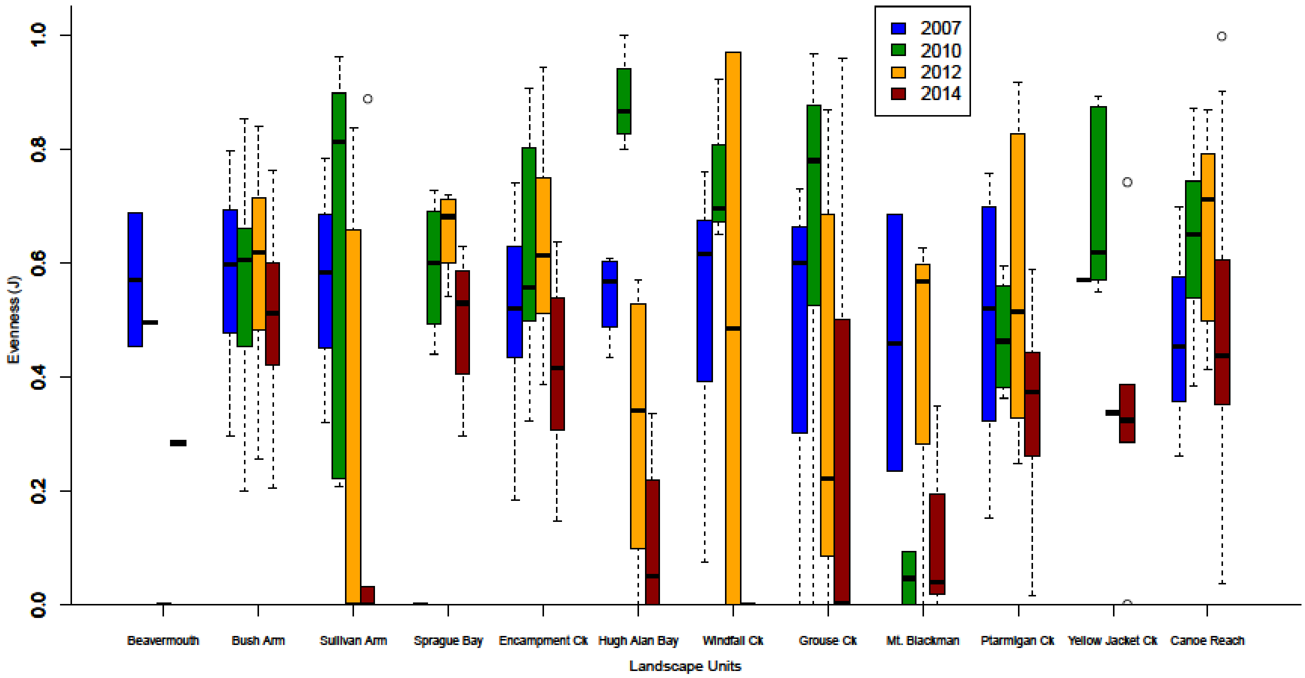


Figure 5-17: Evenness in species' distribution (J) per transect in each landscape unit in 2007, 2010, 2012 and 2014. Landscape units are ordered from south to north.

5.1.5 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, 2012, and 2014 is shown in Figure 5-18. As previously reported (Hawkes *et al.* 2007, 2010, 2013), vegetation communities occur across an elevational gradient and these gradients are fairly consistent between years. The transects that had no vegetation (bare) were all located below 747 m, while the transects in more complex vegetation communities (CT, LH, DR, RD, WD) were located above 749 m. 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. Transects sampled in LL, TP, KS, and WB communities in 2014 were located higher than in previous years, while the opposite was the case for BR and WS communities.

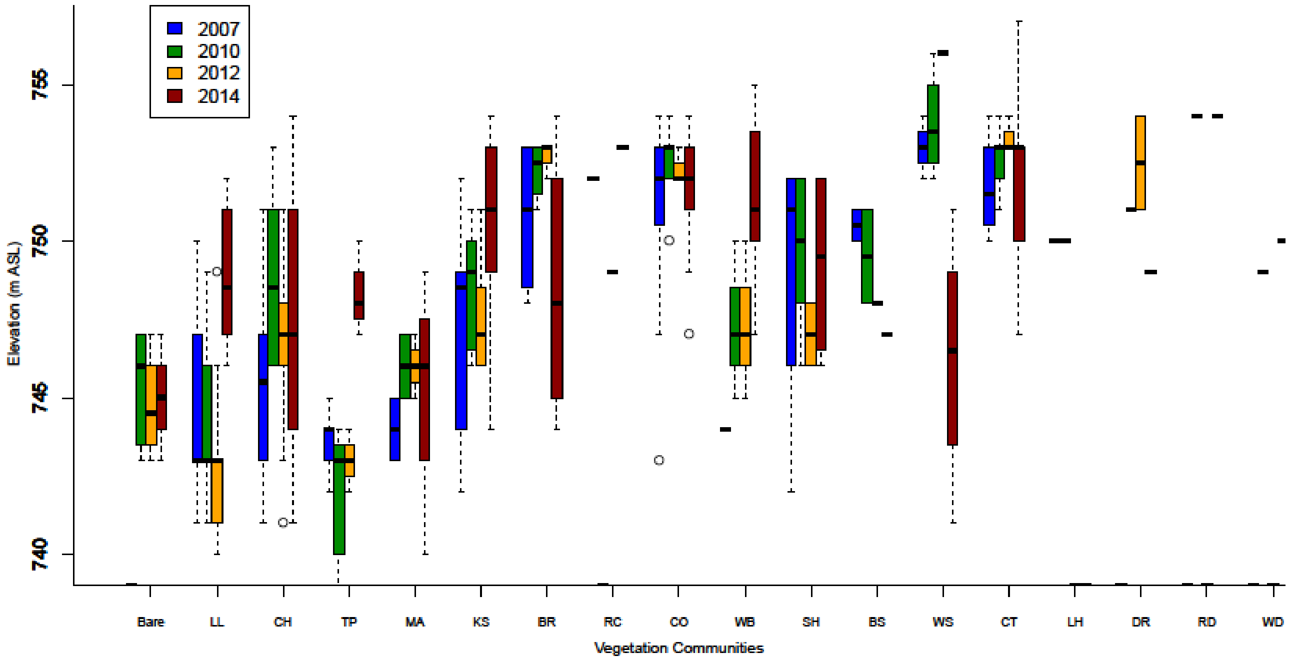


Figure 5-18: Elevational gradient associated with each of the vegetation communities characterized in the drawdown zone of Kinbasket Reservoir in 2007, 2010, 2012, and 2014. Vegetation communities are ordered per seral stage, from pioneering to late seral communities. Refer to Table 4-1 for a description of the vegetation communities.

Species richness per transect varied significantly with elevation. Differences in species richness were statistically significant among years (F=12.1, p=0.00001) and elevation bands (F=6.7, p=0.00001). Interactions were also significant (F=1.8, p=0.006); one-way ANOVAs found significant differences in richness among elevation bands in 2007 (F=17.4, p=0.0001) and 2010 (F=26.5, p=0.0001), and among years for elevations of 743 m (F=4.8, p=0.01), 745 m (F=5.8, p=0.04), 751 m (F=13.8, p=0.0001), 752m (F=16.9, p=0.0001), 753 m (F=17.8, p=0.0001), and 754 m (F=10.3, p=0.0006). Species richness seemed to increase slightly with elevation in the reservoir in 2007 and 2010, but not in 2012 or 2014. Richness declined significantly among years at 743 m, 745 m, and at all elevations above 750 m. Richness was stable or slightly higher in 2014 at elevations of 741 m, 744 m, and from 746 m to 750 m (Figure 5-19).

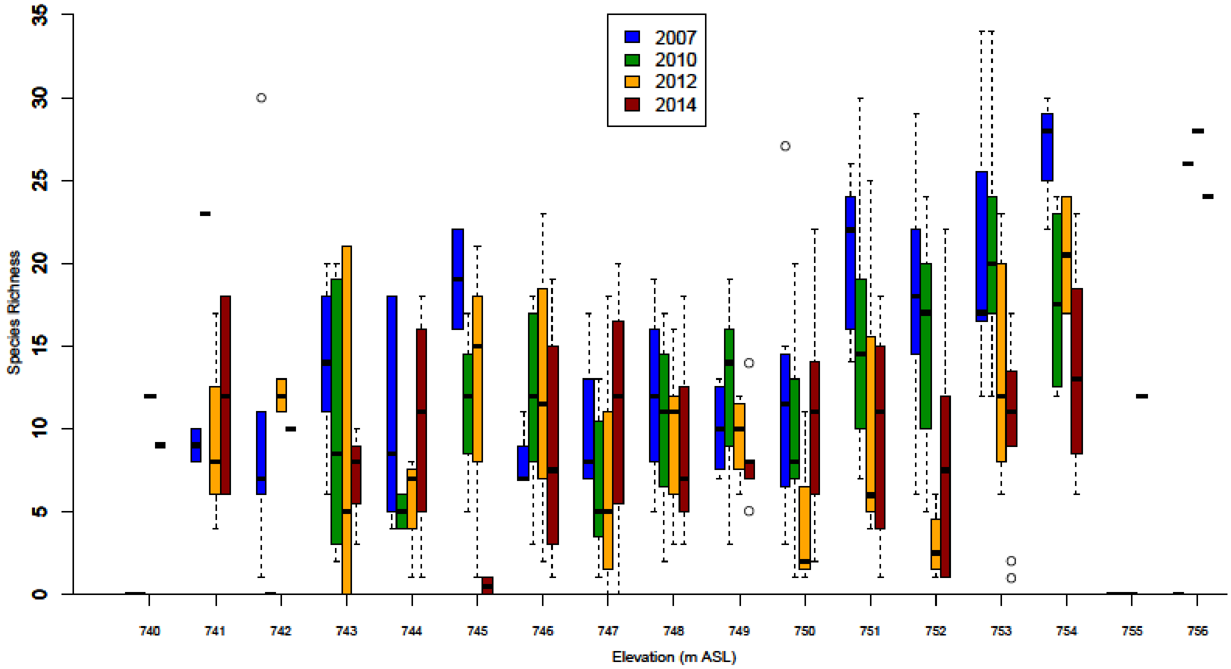


Figure 5-19: Species richness of vegetation per transect in relation to elevation, over time. Refer to Figure 5-9 for boxplot interpretation.

In contrast to richness, neither diversity nor evenness of vegetation exhibited strong directional patterns in relation to elevation (Figure 5-20 and Figure 5-21), although diversity did vary significantly across elevation bands and appeared to increase slightly with elevation. Differences in species diversity were statistically significant among elevation bands (F=3.6, p=0.00004), and among years (F=15.6, p=0.00001). Interactions were not significant (p>0.05). Species diversity varied significantly among years and elevation bands; once again, diversity was generally lower in 2014 than in previous years for most elevations (Figure 5-20). That was especially the case for the elevations of 743 m, 744 m, 747 m, 748 m, 751 m, 752 m, and 753 m. Diversity was fairly stable at low elevations. The tendencies were similar for evenness at the various elevation bands, with evenness being generally lower in 2014 than in previous years, especially at elevations of 751 to 753 m (Figure 5-21).

Differences in species evenness were not statistically significant among elevation bands (p>0.05), but were among years (F=15.6, p=0.00001). Interactions were significant (F=1.6, p=0.02); one-way ANOVAs found significant differences in evenness among elevation bands in 2007 (F=14.45, p=0.0001) and 2014 (F=2.9, p=0.003), and among years for elevation bands of 745m (F=6.6, p=0.03), 747m (F=7.65, p=0.0006), 751m (F=7.0, p=0.002), 752m (F=5.6, p=0.004), and 753m (F=10.9, p=0.0001).

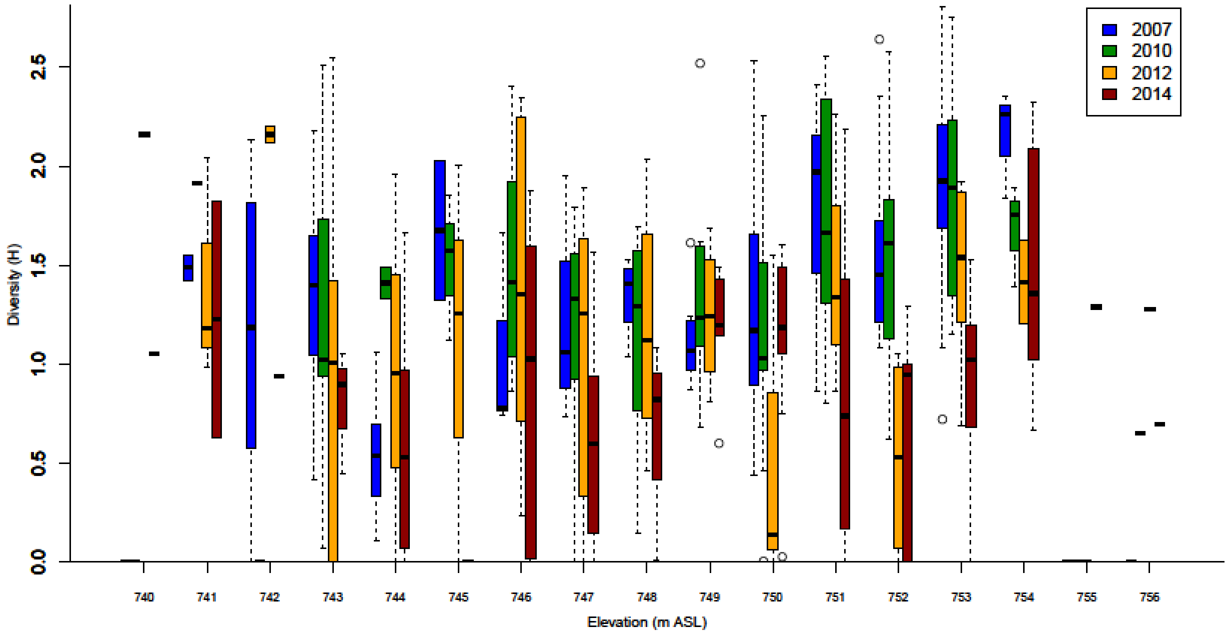


Figure 5-20: Species diversity (Shannon's H) per transect in relation to elevation, over time.

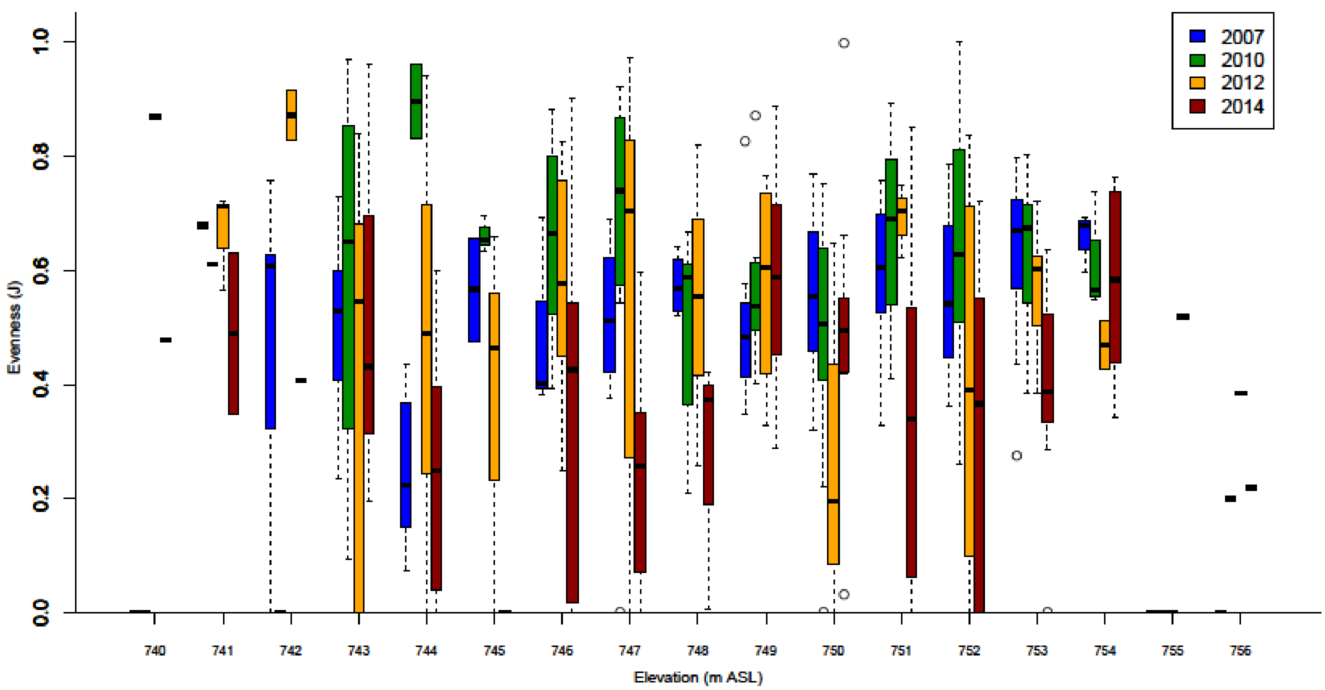


Figure 5-21: Evenness of species' distribution (J) per transect in relation to elevation, over time.

5.1.6 Vegetation and Environmental Variables

All variables used in the RDA and MRT varied substantially across all transects sampled (Table 5-4), which was expected given the elevations across which all transects were sampled (i.e., 740–757 m ASL). The range of values associated with most variables measured in 2014 was similar to 2012.

Table 5-4: Variation in environmental variables across the 96 transects sampled in 2014. All variables were included in the RDA and MRT.

Variable	Acronym	Unit	Mean	S.D.	Min	Max
Elevation	Elev	m (ASL)	749	4	740	757
Slope	Slope	Degrees	5	5	0	33
Aspect	Aspect	Degrees	170	103	0	353
Heatload	Heatload	--	0.50	0.36	0	1
Herb	Herb	per cent	13	18	0	85
Live Organic Matter	OM.live	per cent	19	25	0	97
Dead Organic Matter	OM.dead	per cent	16	24	0	93
Decayed Wood	DecayW	per cent	6	10	0	49
Cover of Rock	Rock	per cent	9	16	0	69
Mineral Soil	M.Soil	per cent	49	36	0	100
Cover of Water	Water	per cent	2	11	0	100
Cover of Tree	Tree	per cent	0	1	0	12
Cover of Shrub	Shrub	per cent	2	9	0	68
Cover of Moss	Moss	per cent	8	21	0	99

Three main groups of vegetation were defined in relation to the environmental variables in Table 5-4, as assessed by the RDA (Figure 5-22). 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 steeper slopes and high cover of rock.

The second group of vegetation was comprised of wetland-associates including Swamp Horsetail (EQUIFLU), Small-flowered Bulrush (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, 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.

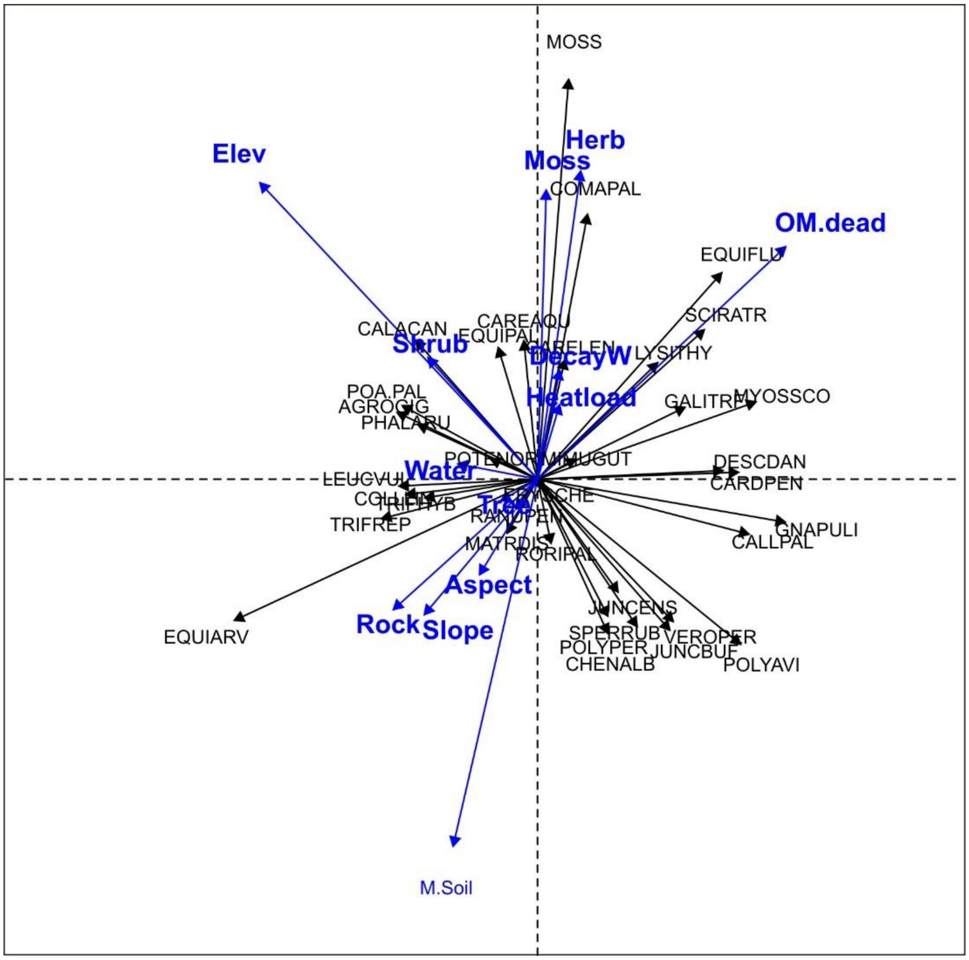


Figure 5-22: Redundancy analysis diagram showing relationships between the cover of 32 main species per transects, and a selection of environmental variables in Kinbasket Reservoir (adj-R^2=0.12, p=0.0001). Axis X shows 6 per cent and axis Y, 5 per cent of the variation associated with the per cent cover of vegetation species. Vectors in black 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.

The multivariate regression tree offers another look at the same datasets and shows which environmental variables were most important in partitioning and describing transects (Figure 5-23). The cover of moss was the first variable to partition transects based on the per cent cover of each species; 16 transects with > 4.5 per cent of moss cover formed the first group. They also corresponded to transects located high in the reservoir.

Elevation was the next variable that created a meaningful split in transects; it partitioned transects with low cover of moss further into categories of above and below 744.5m of elevation. Thirteen transects formed the second group at that partition (< 744.5m), all from early pioneering communities (CH, LL, TP; Table 4-2).

Finally, the cover of dead organic matter constituted the last environmental variables to partition the transects. Two groups of transects were formed at that level; those at high elevations (i.e., ≥ 744.5 m ASL) that had low cover of moss and low cover of dead organic matter (N=57 transects), and those at high elevations with low cover of moss, but high cover of dead organic matter (N=10).

The fraction of variance not explained by the tree (the relative error; 72%) is still fairly high, suggesting that other variables are needed to increase the explanation of the differences among transects.

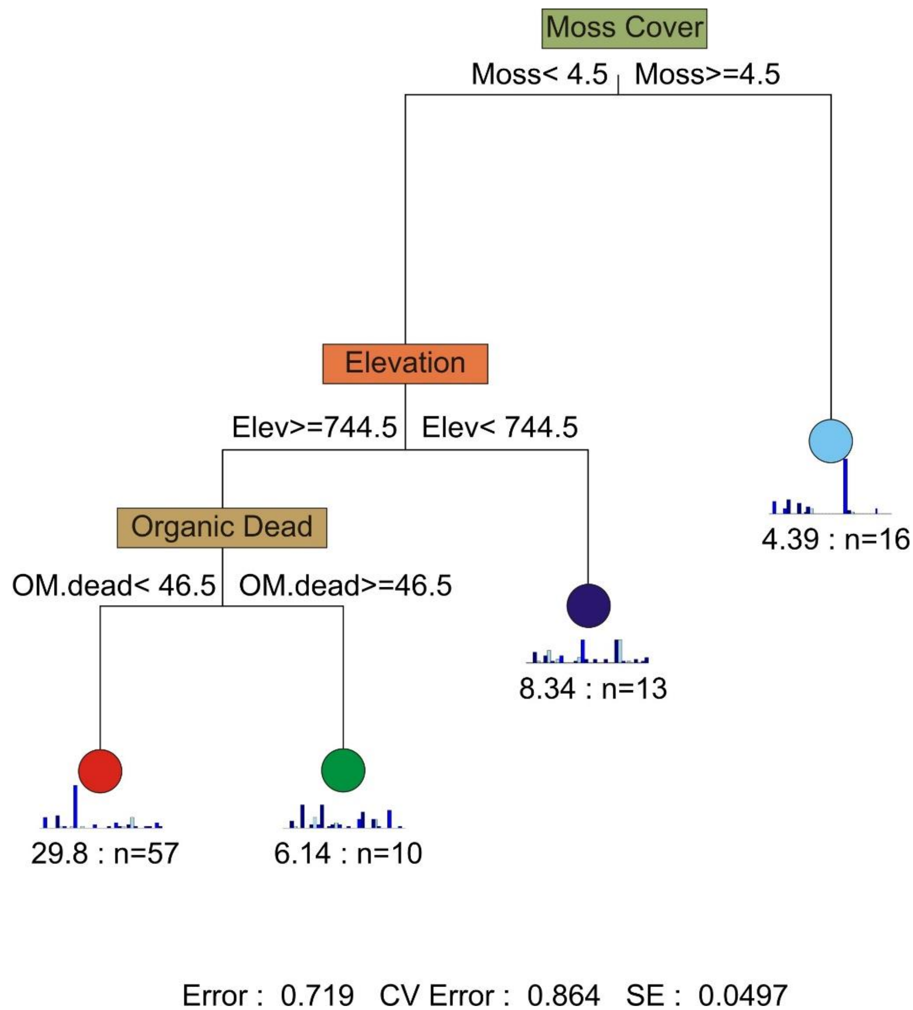


Figure 5-23: Multivariate regression tree (MRT) showing the partition of the transects based on species cover (36 species, present in >7 transects), and a selection of environmental variables. Coloured dots refer to groups as shown on the PCA diagram (Figure 5-24). Bar plots at terminal leaves show the cover of the species pertaining to that group; number below bar plots are relative errors and number of transects per groups.

The partitioning of the 96 transects in the four groups is further displayed on an ordination diagram (Figure 5-24), that illustrates the importance of moss and EQUIARV (horsetail) in explaining the groupings. In fact, a more in-depth analysis of the indicator species (with package "indval") indicated that EQUIARV was the indicator species for the "red" group of transects (indval=0.646, p=0.001), while eight species represented the "green" group, and seven species were indicators for the "blue" group (Figure 5-24). Not surprisingly, moss was a strong indicator for the "turquoise" group of transects (indval=0.813, p=0.001).

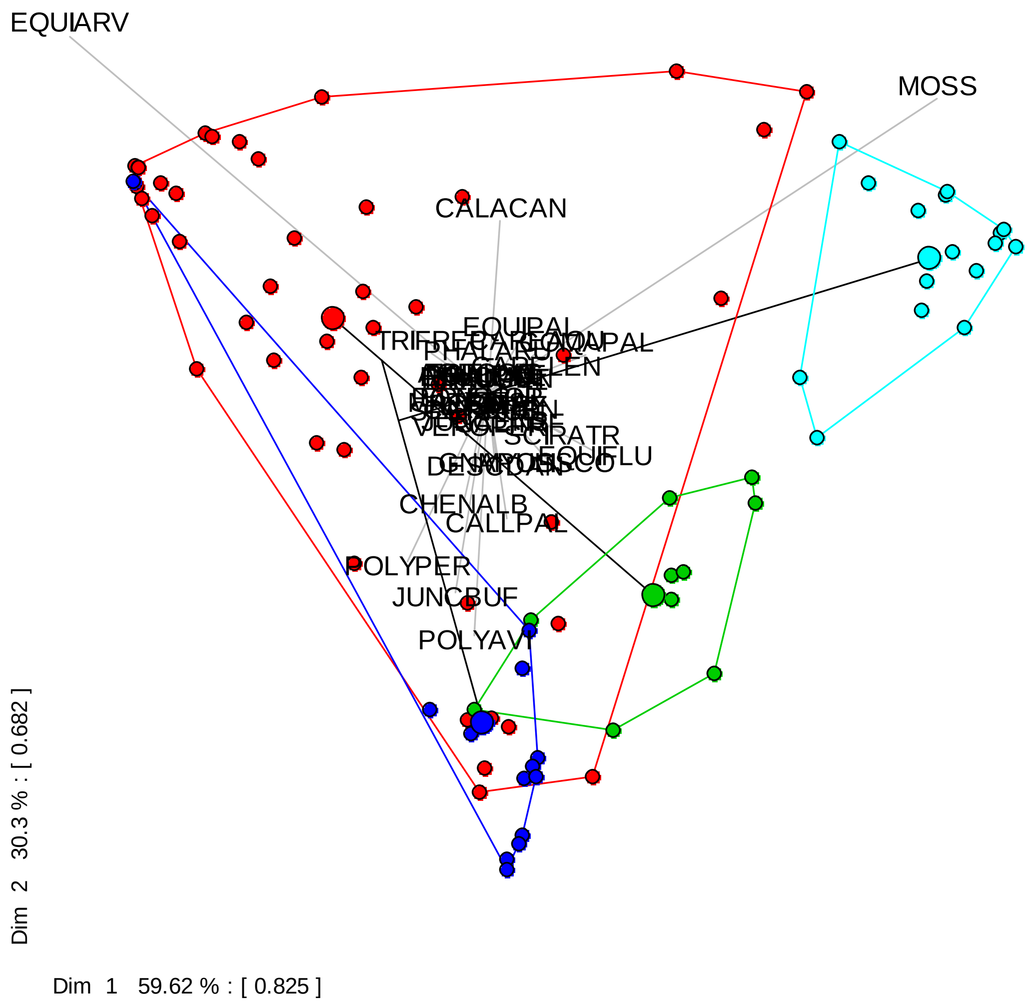


Figure 5-24: Ordination diagram of a PCA showing the relationships among the species included in the multivariate regression tree (Figure 5-23). Axis one expresses 60 per cent of the variation in species cover, while axis 2 expresses 30 per cent. Colours refer to the groups of transects that clustered in each leaf of the multivariate regression tree.

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 landscape units except Succour Creek and Sprague Bay, as these sites were added in 2010. Spatial extent of vegetation increased in most landscape units, especially after 2007 (Table 5-5). The spatial extent of vegetation increased or stayed the same between 2012 and 2014. Increases in total vegetation cover are related to refinements in mapping. In 2014, there were also 96.18 ha of vegetation that was not attributed to any landscape unit; that vegetation was mapped as pertaining to the DI and SW communities. The addition of these two communities in 2014 contributed to net increases in the total mapped area for 10 of the 15 landscape units (Table 5-5). The total area mapped has increased over time, which is related to increases in the total area captured by aerial photos. For most analyses, the area of vegetation mapped between 741 m and 754.38 m ASL is used for comparisons.

Table 5-5: Total spatial extent of vegetation (hectares) in each landscape unit since 2007 from aerial photography. Landscape units are ordered from south to north in Kinbasket Reservoir. '=' indicates no or very minor change, and '+' indicates an increase in spatial extent at a given landscape unit between 2007 and 2014. Differences in average spatial extent were statistically significant among landscape units (F=5.3, p=0.002), but not among years (p> 0.05). Interactions were not significant either (p> 0.05).

Landscape Unit	Year				Change from 2007 (ha)[1]	Change from 2007 (per cent)[2]	Change from 2012 (per cent)[2]	Direction of Change (2012 vs. 2014)
	2007	2010	2012	2014				
Beavermouth	23.13	26.31	26.27	26.13	3.00	11.5%	-0.5%	=
Bush Arm	896.43	1021.86	1021.23	1243.73	347.30	27.9%	17.9%	+
Succour Creek	--	121.36	121.46	149.75	28.39	19.0%	18.9%	+
Sullivan Arm	1.50	1.85	1.82	2.31	0.81	35.1%	21.2%	+
Sprague Bay	--	33.41	33.40	35.00	1.59	4.5%	4.6%	=
Encampment Creek	57.02	68.39	68.51	163.34	106.32	65.1%	58.1%	+
Howard Creek	7.39	11.64	11.63	16.15	8.76	54.2%	28.0%	+
Hugh Alan Bay	35.81	37.33	36.98	40.27	4.46	11.1%	8.2%	=
Windfall Creek	10.54	12.38	12.89	13.80	3.26	23.6%	6.6%	=
Grouse Creek	4.94	4.98	4.98	4.93	-0.01	-0.1%	-1.0%	=
North of Grouse Creek	7.76	7.78	7.93	9.44	1.68	17.8%	16.0%	+
Mount Blackman	4.04	4.15	4.22	5.31	1.27	23.9%	20.5%	+
Ptarmigan Creek	15.73	15.79	15.88	23.31	7.58	32.5%	31.9%	+
Yellowjacket Creek	31.14	31.81	31.81	36.48	5.34	14.6%	12.8%	+
Canoe Reach	683.17	770.64	771.78	897.34	214.17	23.9%	14.0%	+
Total	**1778.60**	**2169.68**	**2170.79**	**2667.29**	**--**	**--**	**--**	**--**

[1]Change was computed compared to spatial extent in 2010 when the landscape unit was not sampled in 2007

[2]Change needs to be >10 per cent of 2014 spatial extent to be considered ecologically meaningful

The spatial extent of vegetation increased in some vegetation communities from 2007 to 2012, but generally decreased in 2014 (e.g., LH, CT, SH; Table 5-6). In the case of late-seral communities (e.g., CT, LH, MC, and WD), the spatial extent of vegetation decreased steadily since 2007. A couple of communities increased in spatial extent since 2007 (e.g., pioneering communities TP and MA); while others were either stable over time (e.g., KS, RD, WB), or increased from 2007 to 2010 and were stable afterwards (e.g., BR). The extent of two communities – SH and WD – have declined over time, which is related to refinements in mapping and for the SH community due to the increase in the DR community in those polygons. The RC community has also declined over time, which could be related to reservoir operations, particularly in 2012 and 2013 when Kinbasket Reservoir was surcharged.

Table 5-6: Total spatial extent of vegetation (hectares) in each vegetation community since 2007 from aerial photography. Vegetation communities are ordered from early pioneering to late seral stages, in Kinbasket Reservoir. '=' indicates no or very minor change, '-' indicates a decrease in spatial extent of a given vegetation community between 2007 and 2014, and '+' means an increase in spatial extent. Differences in average spatial extent were statistically significant among vegetation communities ($F=12.4$, $p=0.0002$), and among years ($F=5.46$, $p=0.03$). Interactions were not significant ($p> 0.05$).

Vegetation Community	Year				Change from 2007 (ha)[1]	Change from 2007 (per cent)[2]	Change from 2012 (per cent)[2]	Direction of Change (2012 vs. 2014)
	2007	2010	2012	2014				
LL	463.50	719.08	713.09	854.20	390.70	45.74	16.52	+
CH	177.12	279.63	281.34	287.88	110.76	38.47	2.27	=
TP	88.99	266.87	265.03	302.25	213.26	70.56	12.31	+
MA	106.06	110.20	110.44	129.62	23.56	18.18	14.80	+
KS	216.10	210.17	215.57	215.56	0.54	-0.25	0.00	=
BR	16.73	41.50	40.68	40.94	24.21	59.14	0.64	=
RC	9.37	31.47	27.98	25.39	16.02	63.10	-10.20	-
RD	--	0.59	0.59	0.57	0.02	-3.69	-3.69	=
CO	146.02	135.67	125.26	146.17	0.15	0.10	14.31	+
WB	4.46	128.85	129.71	143.88	139.42	96.90	9.85	=
SH	145.84	52.41	55.06	43.26	102.58	-237.12	-27.28	-
BS	9.28	12.02	10.69	10.93	1.65	15.10	2.20	=
WS	35.70	34.47	32.39	38.99	3.29	8.44	16.93	+
CT	41.37	20.24	18.65	17.14	24.23	-141.37	-8.81	=
LH	3.53	0.52	0.52	0.52	3.01	-574.95	0.57	=
MC	18.33	0.22	0.19	0.59	17.74	-3006.78	67.80	+
DR	25.92	36.83	47.86	61.20	35.28	57.65	21.80	+
FO	15.85	18.99	16.56	238.63	222.78	93.36	93.06	+
WD	254.19	69.99	79.21	56.33	197.86	-351.25	-40.62	-
DI	--	--	--	23.49	--	--	--	--
SW	--	--	--	72.69	--	--	--	--
Total	**1778.36**	**2169.72**	**2170.82**	**2614.05**	**1527.06**	**--**	**--**	**--**

[1]Change for community RD was computed between 2010, 2012, and 2014

[2]Change needs to be >10 per cent of 2014 spatial extent to be considered ecologically meaningful

The variation in size among polygons in each vegetation community is illustrated by Figure 5-25. Large polygons were mapped mostly for early pioneering vegetation communities (i.e., LL, TP, and MA), with some polygons reaching over 200 ha. However, the large majority of polygons were much smaller than 50 ha (average: 6.1 ha, SD=21.6 ha, median=1.6 ha). Notably, the WD community had larger polygons than other late-seral communities.

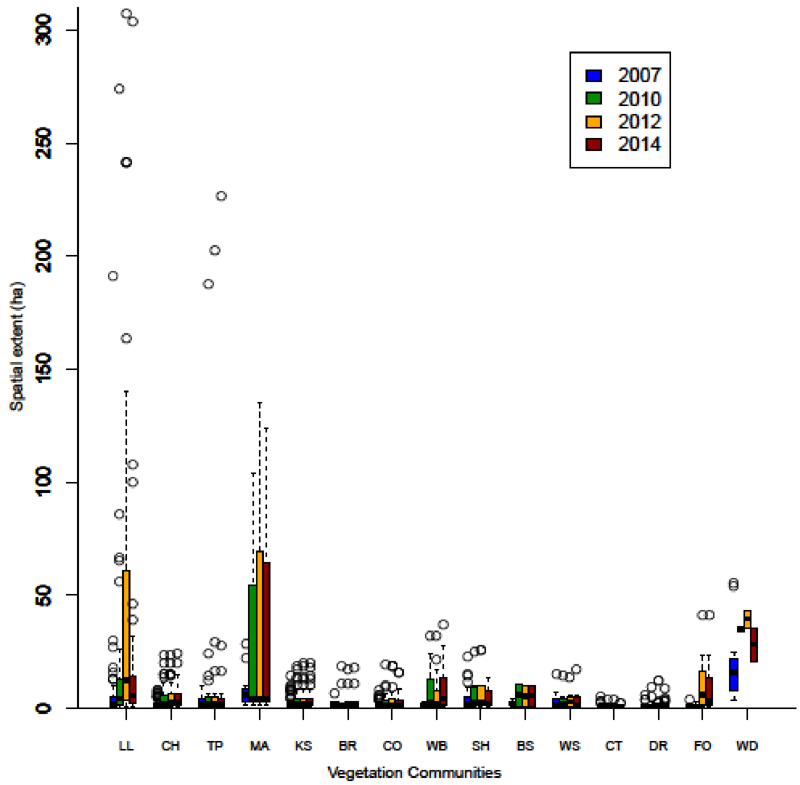


Figure 5-25: Variation in spatial extent over time across the different vegetation communities in Kinbasket Reservoir. Vegetation communities are ordered from early pioneering to late seral stages.

The distribution of vegetation communities by landscape unit and year is shown in Figure 5-26. 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 2012, only three communities were mapped for BM, with the CH covering the largest area. This 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, in agreement with the greater spatial extent of mapped vegetation communities within these units.

The vegetation community with the largest spatial extent in 2014 was the pioneering LL community in Bush Arm and Canoe Reach; as was the case in 2007 and 2012 (Figure 5-26). The spatial extent of the LL community has been relatively stable over time. In general for the three years, pioneering communities (i.e., LL, CH, MA, and KS) had the largest spatial extent mapped in two landscape units: Bush Arm, and Canoe Reach. The CO community in Bush Arm and SH in Canoe Reach were also larger than most other communities in those landscape units. WD was only mapped in Canoe Reach, and its spatial extent decreased substantially since 2007 (Table 5-6, Figure 5-26). Most landscape units had much smaller spatial extents of vegetation communities than Canoe Reach and Bush Arm. Encampment Creek and Hugh Alan Bay were the reaches with the second largest communities (e.g., CH, KS, CO, and FO in Encampment Creek; and LL, CH, KS, and CO communities in Hugh Alan Bay).

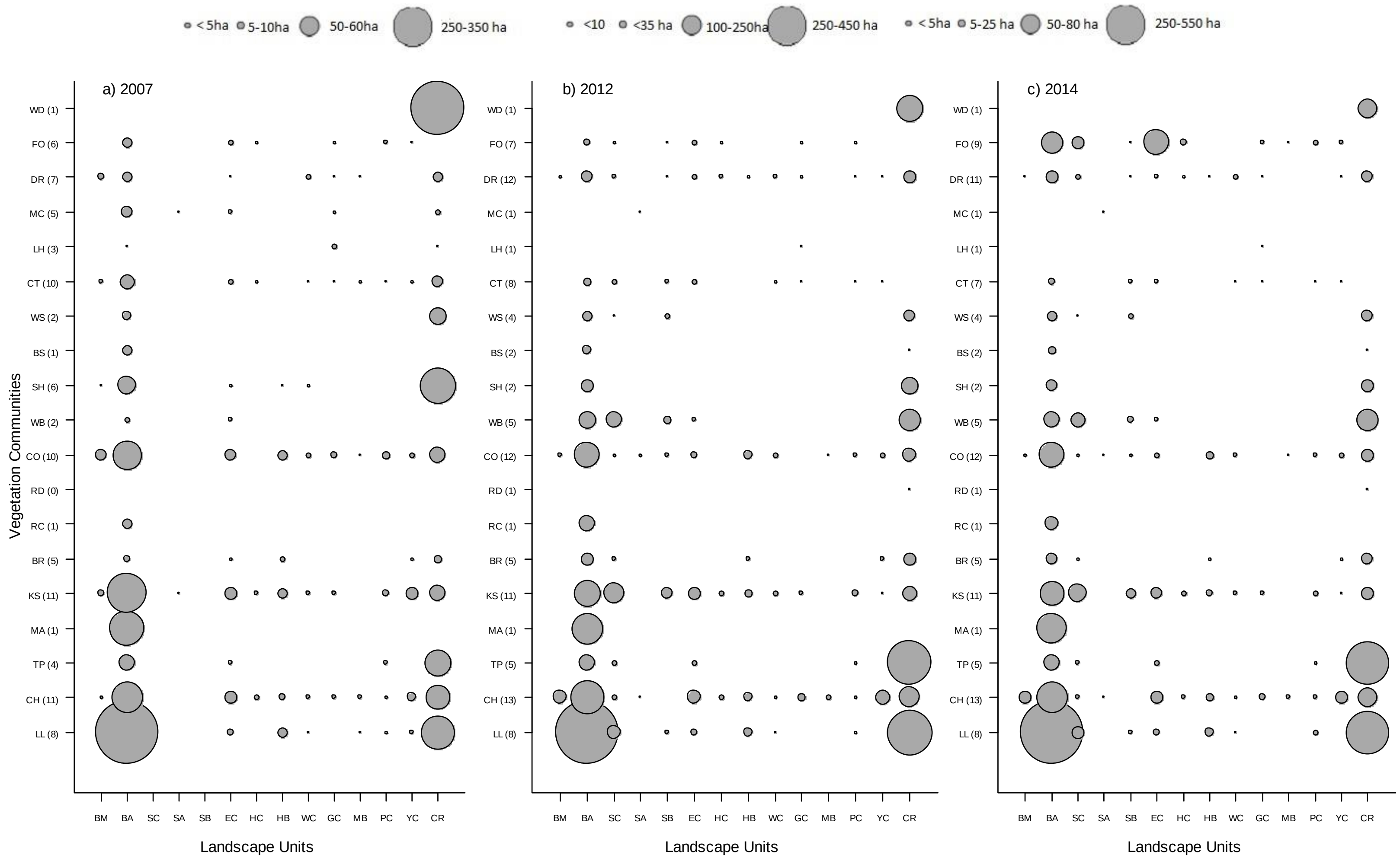


Figure 5-26: **The relative distribution of each vegetation community by year and landscape unit. Vegetation community codes are defined in Table 4-1.** The size of the points is proportional to the communities' spatial extent in the landscape unit and within a given year. Note that the size of points is not comparable across years. 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 of vegetation was maximal at an elevation of 743 m in Kinbasket Reservoir in 2014 (Figure 5-27). However, the number of vegetation communities mapped increased with elevation until 747 m, whereupon they stayed more or less stable between 17 and 19 communities as elevation increased. This is consistent across all years. Elevations below 744 m had less than 14 vegetation communities, and the lowest elevation (741 m) had only eight communities. At an elevation of 754 m, the spatial extent of vegetation was the lowest with about 120 ha.

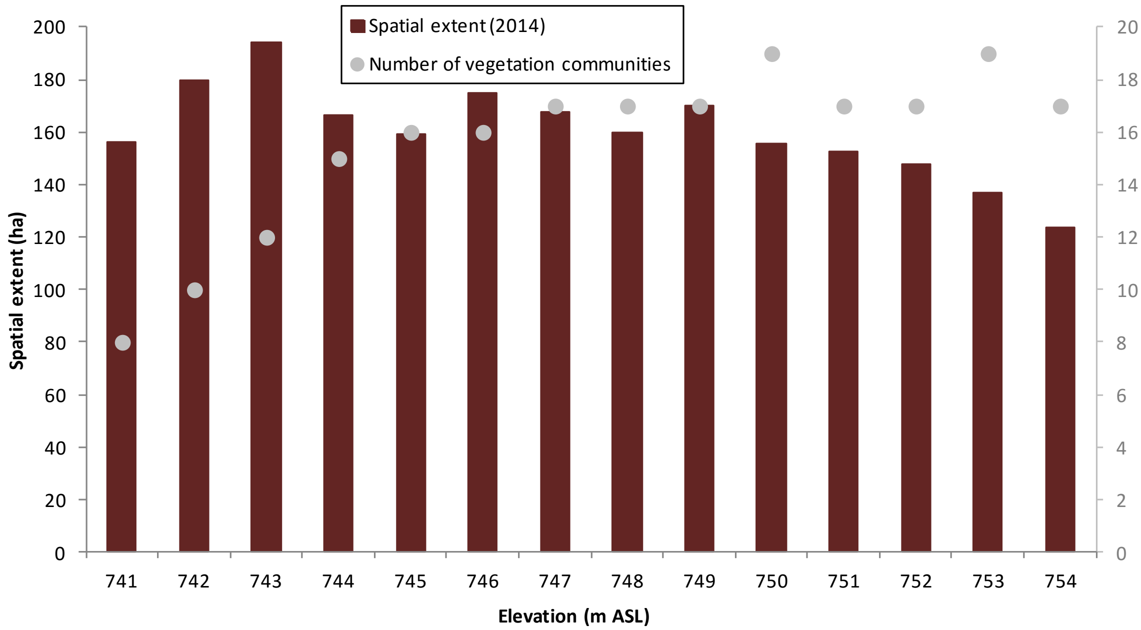


Figure 5-27: Total spatial extent (left axis) and number of vegetation communities (right axis) per elevation band in 2014.

5.2.2 Vegetation Communities and Landscape Unit

The distribution and number of vegetation communities mapped for each landscape unit in 2014 was similar to previous year and higher than 2010 and 2012 for some units (Figure 5-28). Bush Arm and Canoe Reach had the highest number of vegetation communities, followed by Encampment Creek and Succour Creek. That trend is consistent over time, with the number of vegetation communities being either stable over the four years, or increasing slightly in 2014 compared to 2010 or 2012. The number of vegetation communities was typically higher or the same in 2007 than in subsequent years.

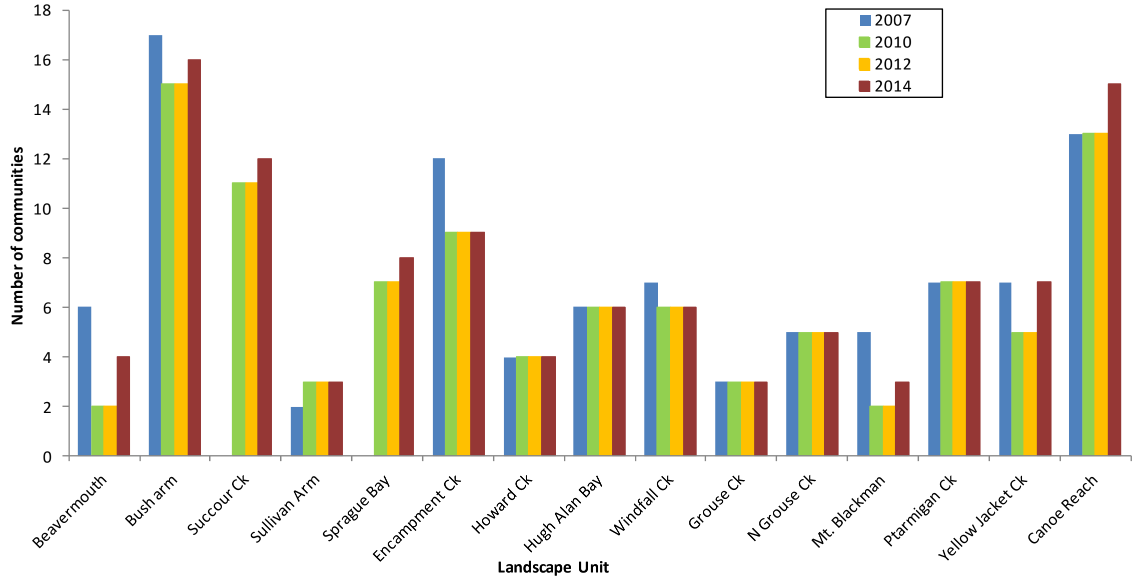


Figure 5-28: Number of vegetation communities mapped per landscape unit in 2007, 2010, 2012, and 2014. Landscape units are ordered from south to north.

Diversity associated with vegetation communities has remained relatively stable over time, except in 2007 which typically had higher diversity (sometimes markedly, such as at Beavermouth) (Figure 5-29).The apparent changes between 2007 and subsequent years are likely due to the changes in mapping that occurred after 2007. Alternatively, 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.

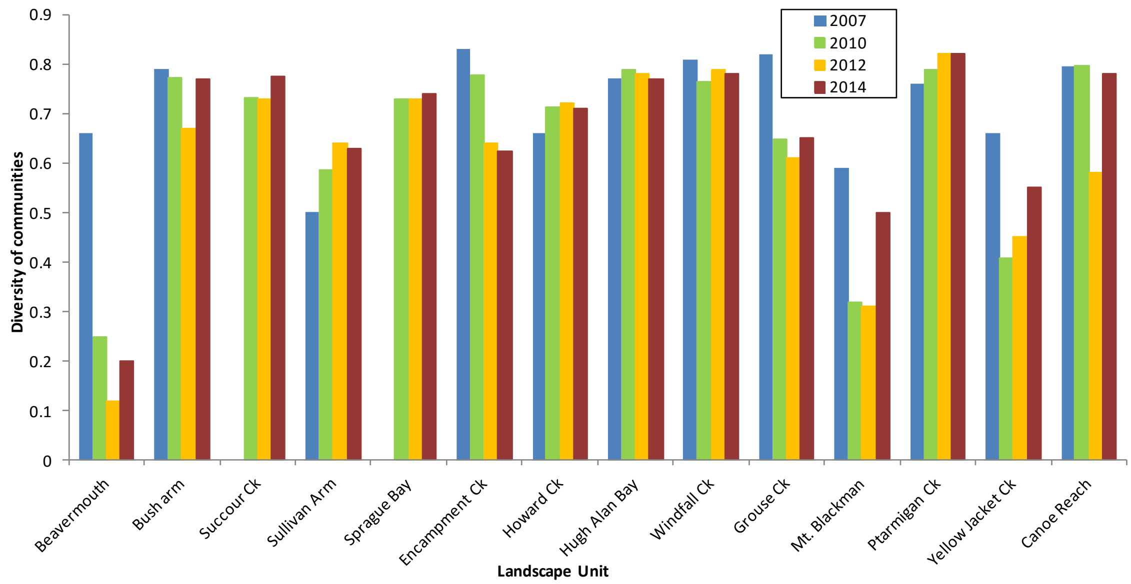


Figure 5-29: Diversity (Simpson's index) of vegetation communities mapped per landscape unit in 2007, 2010, 2012, and 2014. Landscape units are ordered from south to north.

Table 5-7 details the changes in vegetation communities mapped for each landscape units between 2007 and 2014. In general, the same communities were sampled in 2010, 2012, and 2014, but those communities were often different than in 2007. For example, in Sullivan Arm the KS and MC communities were mapped in 2007, while CH, CO, and MC were the three communities mapped in 2010, 2012, and 2014. See Figure 5-26 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.

Table 5-7: 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 at each landscape unit, and the total row (e.g., Beavermouth Total) indicates the years communities were present in given landscape units. The grand total corresponds to the total number of vegetation communities that were mapped over the four years. Landscape units are ordered from south to north, and vegetation communities ordered from pioneering to late seral stages.

Landscape Unit	Year	Vegetation Communities																			Total
		LL	CH	TP	MA	KS	BR	RC	RD	CO	WB	SH	BS	WS	CT	LH	MC	DR	FO	WD	
Beavermouth	2007																				6
	2010																				2
	2012																				2
	2014																				3
	Total		4			1				4	1				1			2			6
Bush Arm	2007																				17
	2010																				15
	2012																				15
	2014																				15
	Total	4	4	4	4	4	4	4		4	4	4	4	4	4	1	1	4	4		17
Succour Creek	2007																				
	2010																				11
	2012																				11
	2014																				10
	Total	3	3	3		3	3			3	3			3	2			3	3		11
Sullivan Arm	2007																				2
	2010																				3
	2012																				3
	2014																				3
	Total		3			1				3							4				4
Sprague Bay	2007																				--
	2010																				7
	2012																				7
	2014																				8
	Total	3				3				3	3			3	3			1	3		8
Encampment Creek	2007																				12
	2010																				9
	2012																				9
	2014																				9
	Total	4	4	4		4	1			4	4	1			4		1	4	4		12
Howard Creek	2007																				3
	2010																				4
	2012																				4
	2014																				4
	Total		4			4									1			3	4		5
Hugh Alan Bay	2007																				6
	2010																				6
	2012																				6
	2014																				6
	Total	4	4			4	4			4		1						3			7
Windfall Creek	2007																				7
	2010																				6
	2012																				6
	2014																				6
	Total	4	4			4				4		1			4			4			7
Grouse Creek	2007																				7
	2010																				6
	2012																				6
	2014																				6
	Total		4			4				1					4	4	1	4	4		8
Mount Blackman	2007																				5
	2010																				2
	2012																				2
	2014																				3
	Total	1	4							4					1			1	1		6
Ptarmigan Creek	2007																				7
	2010																				7
	2012																				7
	2014																				7
	Total	4	4	4		4				4					4				4		7
Yellow Jacket Creek	2007																				7
	2010																				5
	2012																				5
	2014																				7
	Total	1	4			4	4			4					4			1	2		8
Canoe Reach	2007																				13
	2010																				13
	2012																				13
	2014																				13
	Total	4	4	4		4	4		3	4	3	4	3	4	1	1	1	4		4	16

The number of polygons that changed vegetation community between 2007 and 2014 was > 50 per cent for several vegetation communities (MA, BR, CO, WB, SH, CT, LH), and was maximal for MC communities where almost 90 per cent of the polygons assigned to that community in 2007 changed to another community in 2014 (Figure 5-30).

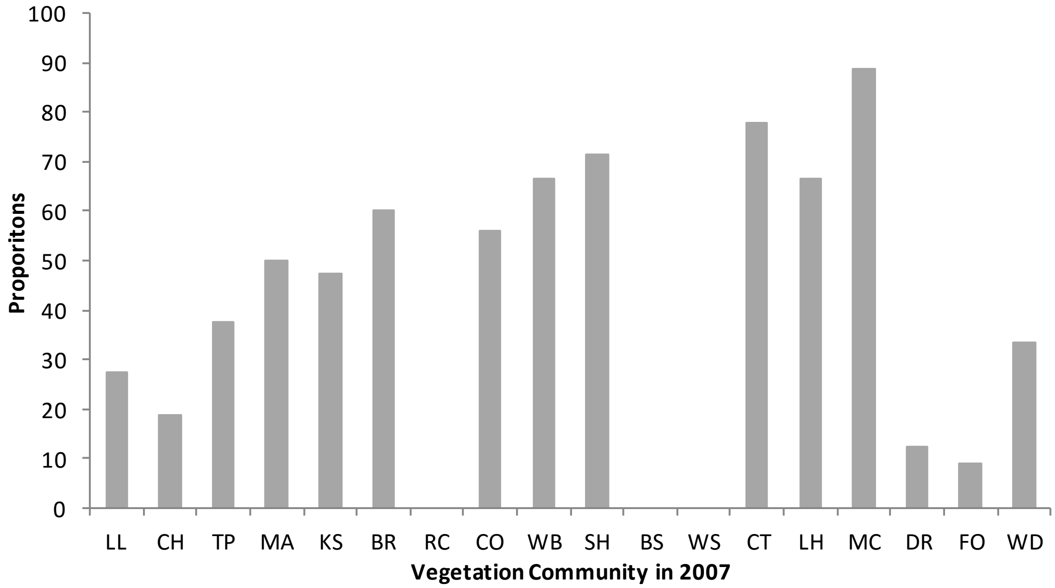


Figure 5-30: Proportion of polygons that changed vegetation community between 2007 and 2014, for each community type that was mapped in 2007. Vegetation communities are ordered from early pioneering to late seral stages.

Only one polygon was mapped in each of the RC and BS communities in 2007 and both polygons were mapped as the same community in 2014; WS communities were also very stable with all six polygons mapped in that community in 2007 remaining the same in 2014 (Table 5-8).

The vegetation communities that had the most polygons mapped consistently between 2007 and 2014 (KS, CO, and CH) were also the ones that were the most unstable (Table 5-8). For example, many of the polygons that were mapped in CO and KS communities in 2007 changed to CH communities in 2014. However, the overall kappa statistic (k=0.51, p=0) suggests moderate agreement between the two years. Almost all vegetation communities showed a significant agreement between the two years, suggesting that the vegetation community assigned to a given polygon over time was not simply attributed by chance.

The only community that did not was WB, where only three polygons could be assessed between the two years, and only one retained the same vegetation community in 2014 compared to 2007. The polygons that changed vegetation community after 2007 often did so in 2010, and their communities remained stable after that. The agreement among years when all four years were considered was higher (k= 0.75, p=0), suggesting that the vegetation communities were substantially more stable after 2007, which coincides with improvements made to the mapping of the communities in the drawdown zone.

Table 5-8: Frequency of vegetation communities of the 220 polygons tested between 2007 and 2014, along with the communities that the polygons changed to in 2014, the individual values of the kappa statistics, and associated p-value. The overall kappa statistic was 0.51 (p=0, 95%CI=0.44, 0.58).

Vegetation Community	2007	2014	Changing to:	k	p-value
LL	22	16	CO(3), KS(2), TP(1)	0.737	0
CH	32	26	CO, KS(3), LL(2)	0.583	0
TP	8	5	KS(2), SH	0.404	0
MA	4	2	CH, TP	0.662	0
KS	38	20	BR(2), BS, CH(7), CO(3), CT, TP(2), WB(2)	0.448	0
BR	5	2	KS, CO, CH.	0.347	0
RC	1	1	--	--	--
CO	34	15	CH(9), CT(4), DR, KS(3), TP, WS	0.389	0
WB	3	1	TP, SH	0.128	n.s.
SH	14	4	LL(2), TP(3), WB (5)	0.371	0
BS	1	1	--	--	--
WS	6	6	--	0.762	0
CT	18	4	BR, CH(2), CO(5), KS(3), RC, WB, WS	0.225	0.001
LH	3	1	FO, RD	0.495	0
MC	9	1	BR, CH, CO, CT(2), FO, KS(2)	0.181	0.007
DR	8	7	RC	0.816	0
FO	11	10	DR	0.862	0
WD	3	2	TP	0.798	0

Overall, most differences in vegetation characteristics at the landscape level seemed to occur after 2007, either in terms of decline in spatial extent (Table 5-5, Table 5-6; Figure 5-26), identity of communities (Table 5-7), or decline in number and diversity of communities (Figure 5-27, Figure 5-28, Figure 5-29, and Figure 5-30; Table 5-8), although some declines in spatial extent also appear between 2012 and 2014, which is indicative of the dynamic nature of the drawdown zone in Kinbasket Reservoir.

5.2.3 Vegetation Communities, Inundation, and Climatic Variables

5.2.3.1 Reservoir Operations

Since 2007 the water levels in the Kinbasket Reservoir were below average (20 year average calculated before 2007) in spring (March-June), but well above the average from mid-June to the end of fall, which corresponds to the second half of the growing season (Figure 5-31). Water levels in 2012 were particularly high in July and August, while water levels peaked in late August through late November in 2013 and 2014.

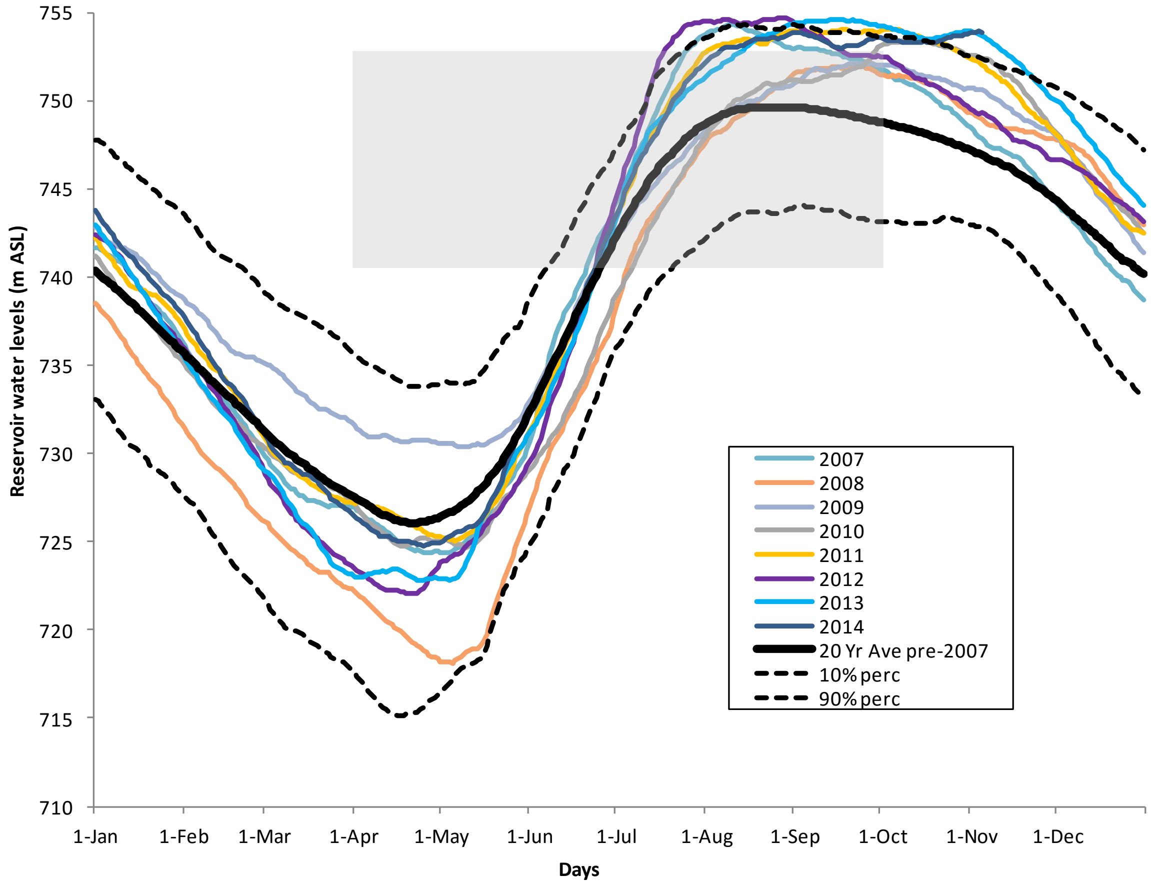


Figure 5-31: Variations in water level (m ASL) over the year, from 2007 to 2014 for Kinbasket Reservoir. The shaded area corresponds to the growing season each year (April-September), and the elevations at which sampling and mapping occur

Those trends are reflected in the proportion of time that the water levels exceeded a given elevation band during the growing season (Table 5-9); even the highest elevation bands were under water for part of the growing season in 2012 and 2013. Elevations of 751 m, 752 m, and 753 m were under water for a higher proportion of time in 2014 than in 2013, but less than in 2012.

The vegetation communities defined and classified in 2007, particularly those in the higher elevation bands (i.e., > 749 m ASL), likely had developed over a number of years when the reservoir did not reach full pool (Figure 5-32). 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 2012 and 2013 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) and Marsh Cudweed-Annual Hairgrass (MA) (Figure 5-9, Figure 5-10, Figure 5-18) 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 exceedance in 2012 and 2013. Between April 1 and September 30 2014, Kinbasket Reservoir did not fill beyond the normal operating maximum of 754.38 m ASL.

Table 5-9: Proportion of time that Kinbasket Reservoir exceeded a given elevation band (m ASL) in the drawdown zone for the months of April – September, 2005 – 2014. For example, in 2014, water levels exceeded the elevation of 741 m for 98 out of 183 days (98/183 = 0.5355). Shaded cells indicate that the reservoir did not exceed a given elevation band

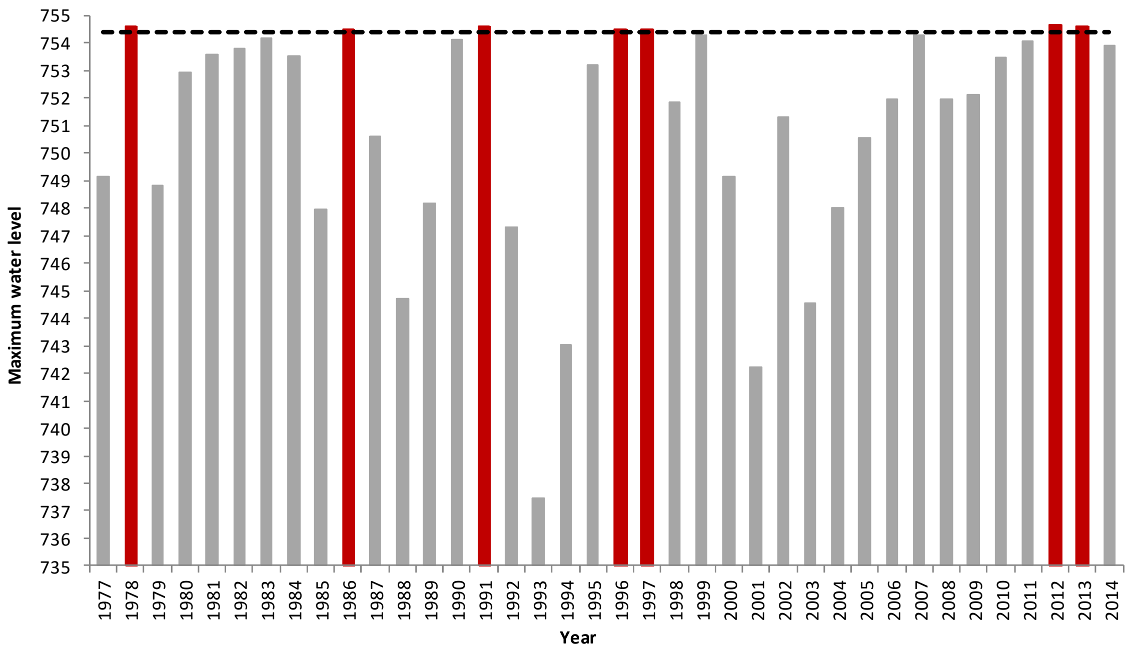
Elevation (m ASL)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
741	0.55	0.59	0.55	0.48	0.53	0.46	0.54	0.54	0.52	0.54
742	0.54	0.58	0.54	0.46	0.51	0.45	0.52	0.53	0.51	0.52
743	0.51	0.56	0.52	0.44	0.48	0.43	0.51	0.52	0.50	0.51
744	0.50	0.54	0.50	0.42	0.46	0.42	0.49	0.50	0.49	0.49
745	0.48	0.52	0.49	0.39	0.43	0.39	0.48	0.50	0.49	0.48
746	0.46	0.51	0.48	0.37	0.40	0.37	0.46	0.49	0.47	0.46
747	0.41	0.49	0.46	0.34	0.37	0.35	0.45	0.47	0.46	0.45
748	0.35	0.48	0.44	0.32	0.34	0.33	0.43	0.46	0.44	0.43
749	0.28	0.45	0.43	0.27	0.31	0.31	0.42	0.45	0.42	0.41
750	0.16	0.43	0.42	0.23	0.24	0.27	0.40	0.44	0.38	0.39
751		0.37	0.40	0.18	0.16	0.19	0.38	0.43	0.35	0.37
752			0.36		0.06	0.03	0.35	0.42	0.30	0.34
753			0.19			0.01	0.32	0.32	0.26	0.29
754			0.07				0.02	0.23	0.19	
754.38								0.18	0.14	

The average depth of water over the vegetation was higher at all elevation bands from 2011 to 2014 than during most of the previous 10 years (Table 5-10). Up to 46 cm of water on average were inundating even above 754m in 2012 and 2013.

Table 5-10: Average depth (m) of water over the vegetation during the growing season at each elevation band in the Kinbasket Reservoir from 2005 to 2014

Elevation (m ASL)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
741	7.20	8.93	10.11	7.81	7.62	8.09	10.32	11.28	10.52	10.06
742	6.41	8.09	9.40	7.07	6.92	7.37	9.63	10.40	9.73	9.36
743	5.66	7.31	8.69	6.31	6.29	6.63	8.83	9.61	8.93	8.55
744	4.77	6.59	7.95	5.61	5.49	5.88	8.11	8.91	8.12	7.81
745	3.96	5.78	7.20	4.97	4.87	5.18	7.37	8.00	7.20	6.98
746	3.09	4.95	6.36	4.30	4.17	4.46	6.53	7.17	6.44	6.20
747	2.43	4.10	5.56	3.54	3.49	3.70	5.75	6.40	5.58	5.41
748	1.76	3.23	4.75	2.75	2.77	2.91	4.94	5.54	4.77	4.66
749	1.08	2.35	3.86	2.16	2.01	2.08	4.12	4.60	4.05	3.83
750	0.39	1.47	3.00	1.49	1.40	1.26	3.27	3.70	3.36	2.97
751	0	0.63	2.10	0.75	0.84	0.57	2.43	2.78	2.62	2.12
752	0	0	1.25	0	0.10	0.50	1.58	1.84	1.97	1.28
753	0	0	0.78	0	0	0	0.68	1.23	1.23	0.41
754	0	0	0.16	0	0	0	0.06	0.46	0.45	0
754.38	0	0	0	0	0	0	0	0.14	0.14	0

The maximum water levels in the reservoir were above the normal operating maximum in seven of the past 37 years (1977 to 2014; Figure 5-32, top), including twice in the past three years (2012 and 2013). The water levels peaked at 753.92m on November 4, 2014 (data available through November 5, 2014), and may have exceeded the normal operating regime later in November 2014. The total annual change in reservoir elevations was similar over time and was not greater during years when the reservoir exceeded the normal operating maximum (Figure 5-32, bottom).



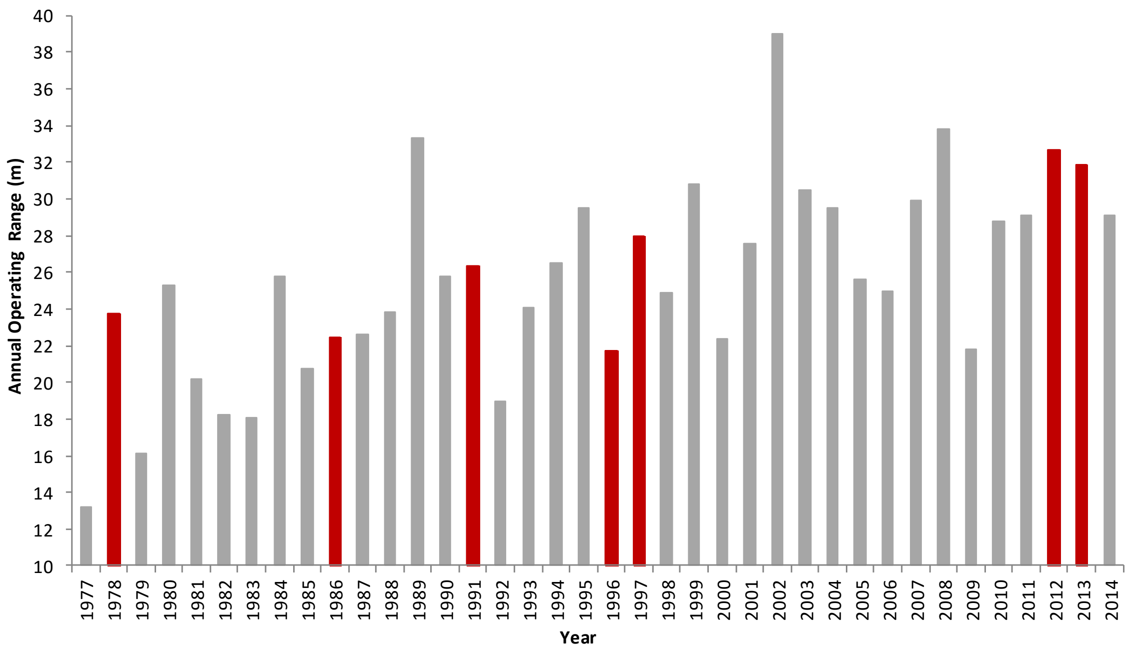


Figure 5-32: Maximum reservoir elevations recorded for Kinbasket Reservoir 1977 through 2014 (top) and annual operating range (bottom). The black dashed line represents the normal operating maximum. Red bars indicate years when that maximum was exceeded

5.2.3.2 Wet Stress and Dry Stress and Climatic Variables

Average monthly temperatures across the growing season (April 1 through September 30) were similar during all implementation years of CLBMON-10 (Table 5-11), 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 5-11: Average temperature (°C), relative humidity (%) and precipitation (mm) associated with the exposed elevation bands in April and September 2007, 2008, 2010, 2012, and 2014

Month	Temperature (°C)					Relative Humidity (%)					Precipitation (mm)				
	2007	2008	2010	2012	2014	2007	2008	2010	2012	2014	2007	2008	2010	2012	2014
April	4.3	2.8	5.3	4.9	4.63	71.2	64.9	64.4	75.4	67.1	79.8	26.7	58.8	166	22.6
May	10.4	10.9	9.1	9.3	9.32	61.5	63.6	60.3	60.7	66.4	54.5	39.1	49.8	31.2	56
June	13.7	13.3	13.7	12.8	13.5	69.8	65.4	63.8	73.6	61.5	84.4	73.3	120.6	243	48
July	18.4	15.5	16.4	17.4	18.5	62.8	66.2	61.8	70	55.8	67.1	104.4	94.8	181	36.8
August	14	15.1	14.7	15.8	16.8	74.6	70.2	72.7	72.7	66.4	103.2	113.2	161.6	72.2	34.2
September	9.6	10	9.5	11.6	11.8	77.3	77	84.9	74.1	74.3	89.2	70.3	295	34.6	49.4
Mean or Sum	**11.7**	**11.3**	**11.4**	**12**	**12.5**	**69.5**	**67.9**	**68**	**71.1**	**65**	**478.25**	**426.96**	**780.6**	**728**	**247**

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). 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 5-33. All elevations were exposed for most of or all of April, May, and June each year with exposure time decreasing in July, August, and September. 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 (GDD) is assumed to be slightly more than 0 per cent.

Figure 5-33 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, 2012 and 2014 relative to 2008 and 2010. The effect of reduced growing degree days on vegetation community establishment and development is likely contributing to the reduction in species richness and diversity observed since 2012.

Month	Year	Elevation (m ASL)													
		741	742	743	744	745	746	747	748	749	750	751	752	753	754
April	2007	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2008	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2009	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2010	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2011	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2012	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2013	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2014	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
May	2007	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2008	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2009	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2010	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2011	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2012	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2013	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2014	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
June	2007	0.70	0.80	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2008	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2009	0.83	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2010	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2011	0.80	0.90	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2012	0.80	0.83	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2013	0.87	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2014	0.80	0.90	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
July	2007	0.00	0.00	0.00	0.00	0.10	0.16	0.26	0.35	0.42	0.52	0.61	0.71	0.84	1.00
	2008	0.16	0.26	0.35	0.48	0.65	0.81	0.94	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2009	0.00	0.00	0.13	0.23	0.42	0.58	0.77	0.97	1.00	1.00	1.00	1.00	1.00	1.00
	2010	0.23	0.32	0.42	0.52	0.65	0.77	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2011	0.00	0.00	0.00	0.06	0.16	0.23	0.32	0.42	0.52	0.61	0.74	0.90	1.00	1.00
	2012	0.00	0.00	0.00	0.00	0.03	0.10	0.19	0.26	0.29	0.35	0.42	0.48	0.58	0.74
	2013	0.00	0.00	0.00	0.06	0.10	0.19	0.26	0.35	0.52	0.71	0.90	1.00	1.00	1.00
	2014	0.00	0.00	0.00	0.06	0.13	0.23	0.32	0.45	0.55	0.65	0.77	0.97	1.00	1.00
August	2007	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.65
	2008	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.35	0.61	0.90	1.00	1.00	1.00
	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.55	1.00	1.00	1.00	1.00
	2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.16	0.35	0.87	1.00	1.00	1.00
	2011	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	1.00
	2012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2013	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.48	0.84
	2014	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	1.00
September	2007	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	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	1.00	1.00	1.00
	2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.63	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	0.80	0.97	1.00
	2011	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.90
	2012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.87
	2013	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2014	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	1.00

Figure 5-33: 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. Only one of these species were recorded in 2014 (Table 5-12).

Table 5-12: 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 from 2007 to 2014. Y = Yes; N = No.

Scientific Name	Common Name	BC CDC Status	Years Documented				
			2007	2008	2010	2012	2014
Carex crawei	Crawe's Sedge	Red-listed	Y	Y	N	Y	N
Carex tonsa[1]	Bald sedge	Blue-listed	Y	N	N	Y	N
Eleocharis elliptica	Elliptic spike rush	Blue-listed	Y	N	Y	Y	Y
Liparis loeselii	Yellow widelip orchid	Red-listed	Y	N	Y	Y	N
Mimulus breviflorus	Short flowered monkey flower	Red-listed	Y	Y	Y	N	N
Mimulus breweri	Brewer's monkey flower	Blue-listed	Y	N	Y	Y	N
Packera plattensis[2]	Plains butterweed	Yellow-listed	Y	Y	Y	Y	N
Juncus stygius[1]	Bog rush	Blue-listed	--	--	--	Y	N
Dryopteris cristata[1]	Crested wood fern	Blue-listed	--	--	--	Y	N
Muhlenbergia glomerata[3]	Marsh muhly	Blue-listed	--	--	--	--	N

[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 plattensis* (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 5-12 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 2014 field season represented the fifth 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 2014 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 271 plant species (including 11 species in 2014 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 2014 differed significantly from that in 2007, although much of the difference was attributable to mapping errors associated with the 2007 data. The spatial extent of communities in 2014 was largely unchanged from 2010 and 2012.

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 2014.

At the same time, species constancy (the proportion of all species observed in 2014 that were also recorded in both 2007, 2010, and 2012) was rather low, averaging 49 per cent for repeat transects and 36 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 MRT) 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. While these results do not impugn the validity of using the vegetation communities defined in 2007 with the 2014 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 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. 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 in 2007, 2012 and 2013.

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. The timing and duration of inundation also influences the number of growing degree days (GDDs) 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, 2010, and 2014, 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 GDDs.

In the case of reservoir vegetation, it would be difficult, without direct experimentation, to separate out the relative importance of wet stress and GDDs 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 GDDs, such that periodic reductions in GDDs (as seen in 2007, 2012, and 2014) 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

Hawkes et al. (2013) discussed vegetation community dynamics in the context of vegetation communities that appeared to be trending in nonparallel directions. Current data suggest that community dynamics and changes in species richness and diversity are associated with reservoir elevation and duration of inundation with both richness and diversity declining over time in communities situated at elevations ≥ 750 m ASL. The decline has been more apparent since 2012 following two successive years of reservoir surcharge and periods of increased inundation at these elevations. Declines in species richness and diversity were also observed in some lower elevations (743 and 745 m ASL) and overall, the trend appears to be declining richness and diversity over time relative. Given these current data, it appears that community dynamics are negatively influenced by reservoir operations and this trend is more apparent at higher elevations in the drawdown zone.

6.3 Landscape Units

For certain landscape units (e.g., Sullivan Arm and Windfall Creek), the full pool event in 2007 and subsequent surcharging in 2012 and 2013 are the most likely explanations for the apparent reduction in species diversity observed since 2007. The surcharging of Kinbasket Reservoir also contributes to increased rates of erosion and sediment deposit, which is particularly evident at Windfall Creek and Hugh Alan Bay. Prevailing wind patterns could also 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,Hawkes et al. 2013). 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 the Toad Rush-Pond-water starwort (TP) community.

At the mapping level, and as noted above, the spatial extent of vegetation mostly increased or stayed the same between 2012 and 2014 and the increases were associated with increases in the total area mapped in 10 of the 15 landscape units as a result of the acquisition of LiDAR data in 2014, which suggests that the 754 m ASL contour is in a different location than suggested by the BC Hydro-derived digital elevation model (DEM). Further mapping work is required to assess the total additional area that would be mapped based on the use of the LiDAR data and previous years of mapping (2007, 2010, and 2012) would need to be updated to the new LiDAR DEM to ensure accurate comparisons between years.

7.0 CONCLUSIONS

Many of the conclusions reached in the last implementation year (Hawkes *et al.* 2013) were supported in the current implementation year. If Kinbasket Reservoir is operated such that near filling or surcharging 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, many of the woody stemmed species are unlikely to remain or become 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. Given that vegetation development and establishment can be a relatively slow ecological process, a longer time series than 10 years may be necessary to assess the full impacts of successive years of high water and surcharge on the vegetation communities in the drawdown zone of Kinbasket Reservoir.

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.

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	Will MQ Be Addressed?	Current Supporting Results	Suggested Modifications to Methods Where Applicable	Sources of Uncertainty
i. What are the existing riparian and wetland vegetation communities in the Kinbasket Reservoir drawdown zone between elevations 741 m to 754 m?	Yes	18 communities delineated in 2007 and 2008. 19 in 2010, 2012 and 2014.	Not all areas of the drawdown zone with existing vegetation have been mapped, which underestimates the total area of existing vegetation. These areas should be included in future assessment of total vegetated area.	Because the entire drawdown zone has not been considered for CLBMON-10, only the areas identified as a priority for sampling in 2007 can be assessed relative to this management question.
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?	Yes	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.	Not all areas of the drawdown zone with existing vegetation have been mapped, which underestimates the total area of existing vegetation. These areas should be included in future assessment of total vegetated area.	The LiDAR data obtained in 2014 suggests that additional areas of the drawdown zone need to be mapped, particularly in areas > 751 m ASL. This would lead to increases in the total cover of vegetation and the addition of at least two new communities. Some areas were assessed based on the LiDAR data in 2014 and ~ 100 ha of additional habitat was mapped.
iii. How do spatial extent, structure and composition of vegetation communities relate to reservoir elevation and site conditions (aspect, slope and soil drainage)?	Yes	The relationship between reservoir elevation and species richness and diversity is starting to become clear: repeated years of high water or surcharging negatively affect these parameters. The spatial extent of most communities has remained stable over time, but some changes might be realized through the use of the LiDAR data and a longer time series of data.	The current duration of this monitoring program may not be long enough to properly assess the effects of repeated high water and surcharge events on existing vegetation.	The longer-term effects of surcharge or repeated years of high water are likely to have a negative effect on the spatial extent of existing vegetation communities, but this assumption requires testing.
iv. Does the current operating regime of Kinbasket Reservoir maintain the spatial extent, structure and composition of existing vegetation communities in the drawdown zone?	Yes	Current data suggest that the current reservoir operating regime (2007 - present) negatively affects species richness and diversity.	See above - the longer term effects of the operating regime on the spatial extent of existing vegetation communities need to be assessed over an appropriate duration.	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.

Management Question	Will MQ Be Addressed?	Current Supporting Results	Suggested Modifications to Methods Where Applicable	Sources of Uncertainty
v. Are there operational changes that can be implemented to maintain existing vegetation communities at the landscape scale more effectively?	Yes	Given the effects of high water and surcharge a reduction in the maximum elevation and duration of inundation would function to maintain existing vegetation at higher elevations. It may be possible to implement physical works to either protect or create habitats in the drawdown zone, which could lead to the maintenance of vegetation communities.	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 maintain or 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.

8.0 RECOMMENDATIONS

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

1. The relative effects of woody debris accumulation and scouring on existing vegetation communities have not been well-characterized. Efforts to obtain even qualitative data on the effects of woody debris on vegetation should be made;
2. Time the aerial photo acquisition in 2016 to coincide with the same phenological stage of vegetation growth in the drawdown zone as previous years. This will ensure a direct comparison of vegetation communities from 2007 to 2014;
3. Continue to acquire aerial photos digitally;
4. The acquisition of LiDAR data in 2014 indicates a disparity between the BC Hydro generated DEM that has been used since 2007 and the actual on-the-ground location of specific elevations. A detailed assessment of the differences between the LiDAR DEM and BC Hydro generated DEM should be made to fully understand if additional work is required to align all existing data (i.e., 2007, 2010, 2012, and 2014) with the LiDAR data. This is particularly important as it appears that additional areas will be mapped in each of the landscape units mapped to date;
5. There are additional areas of the drawdown zone that have vegetation, but are not currently considered under CLBMON-10. This results in an under-estimation of the total area of existing vegetation in the drawdown zone of Kinbasket Reservoir. These additional areas could be mapped to better estimate the total area of the drawdown zone covered by vegetation;
6. 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);
7. Implement field sampling in 2016 when plant growth is as advanced as it was in 2010, 2012 and 2014. Periodic assessments of plant phenology will be made during field work for other studies (e.g., CLMBON-37, CLMBON-61); and
8. Maintain the level of ground truthing between 12 and 15 per cent of the total number of polygons to be consistent with previous years.

9.0 LITERATURE CITED

Auble, G.T., Scott, M.L., Friedman, J.M., 2005. Use of individualistic streamflow-vegetation relations along the Fremont River, Utah, USA to assess impacts of flow alteration on wetland and riparian areas. Wetlands 25: 143–154.

Baldwin, A.H., M.S. Egnotovich, and E. Clarke. 2001. Hydrologic change and vegetation of tidal freshwater marshes: field, greenhouse, and seed-bank experiments. Wetlands 21: 519–531.

Banach, K., A.M. Banach, L.P.M. Lamers, H. De Kroon, R.P. Bennicelli, A.J.M. Smits, and E.J.W. Visser. 2009. Differences in flooding tolerance between species from two wetland habitats with contrasting hydrology: implications for vegetation development in future floodwater retention areas. Annals of Botany 103: 103.

BC Hydro. 1983. Keenleyside Power Plant Project - Review of Design Flood Criteria, Hydroelectric Engineering Division report no. H1497, March 1983.

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

BC Hydro. 2007. Columbia River project water use plan. BC Hydro Generation, Burnaby BC. 41 pp.

Beauchamp, V.B. and J.C. Stromberg. 2008. Changes to herbaceous plant communities on a regulated desert river. River Research and Applications, 24: 754–770.

Blanch, S.J., G.G. Ganf, K.F. Walker. 1999. Tolerance of riverine plants to flooding and exposure indicated by water regime. Regulated Rivers: Research and Management 15: 43-62.

Brock, M.A., D.L. Nielsen, and K. Crossle. 2005. Changes in biotic communities developing from freshwater wetland sediments under experimental salinity and water regimes. Freshwater Biology 50: 1376–1390.

Budelsky, R.A. and S.M. Galatowitsch. 2000. Effects of water regime and competition on the establishment of a native sedge in restored wetlands. Journal of Applied Ecology 37: 971–985.

Bunnell, F.L., L.L. Kremsater, and E. Wind. 1999. Managing to sustain vertebrate richness in forests of the Pacific Northwest: relationships within stands. Environmental Review, 9: 97–146

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

Cherry, J.A. and L. Gough. 2006. Temporary floating island formation maintains wetland plant species richness: the role of the seed bank. Aquatic Botany 85: 29–36.

Crossle, K. and M.A. Brock. 2002. How do water regime and clipping influence wetland plant establishment from seed banks and subsequent reproduction? Aquatic Botany 74: 43–56.

De'ath G.D., and K.E. Fabricious. 2000. Classification and regression trees: a powerful yet simple technique for ecological data analysis. Ecology, 81(11): 3178-3192.

De'ath G.D. 2002. Multivariate regression trees: a new technique for modeling species-environment relationships. Ecology, 83(4): 1105-1117.

Della Bella, V., M. Bazzanti, M.G. Dowgiallo, and M. Iberite. 2008. Macrophyte diversity and physico-chemical characteristics of Tyrrhenian coast ponds in central Italy: implications for conservation. Hydrobiologia 597: 85–95.

Edwards, A.L., D.W. Lee, and J.H. Richards. 2003. Responses to a fluctuating environment: effects of water depth on growth and biomass allocation in *Eleocharis cellulosa* Torr (Cyperaceae). Canadian Journal of Botany 81: 964–975.

Enns, K., P. Gibeau and B. Enns. 2009. CLBMON-12 Arrow Lakes Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis: 2009 Final Report. Report prepared by Delphinium Holdings Inc. for BC Hydro, 99 pp. + Apps

Enns, K.A., P. Gibeau & B. Enns. 2008. Arrow Lakes Reservoir Inventory of Vegetation Resources – 2007 to 2008 Final Report. Report prepared by Delphinium Holdings Inc. for BC Hydro.

Greet, J., J.A. Webb, and R.D. Cousens. 2011. The importance of seasonal flow timing for riparian vegetation dynamics: a systematic review using causal criteria analysis. Freshwater Biology 56: 1231–1247.

Hawkes, V.C., M.T. Miller, and P. Gibeau. 2013. CLBMON-10 Kinbasket Reservoir Inventory of Vegetation Resources. Annual Report – 2012. LGL Report EA3194A. Unpublished report by LGL Limited environmental research associates, Sidney, BC, for BC Hydro Generations, Water License Requirements, Burnaby, BC. 86 pp + Appendices.

Hawkes, V.C. 2008. Kinbasket woody debris removal: Impacts to monitoring program CLBMON-10 Kinbasket Reservoir inventory of vegetation resources. LGL Report EA1986.1. Unpublished report by LGL Limited environmental research associates, Sidney, BC, for BC Hydro Generations, Water License Requirements, Burnaby, BC. 21 pp.

Hawkes, V.C. and J.E. Muir. 2008. CLBMON-10 Kinbasket Reservoir Inventory of Vegetation Resources. Annual Report – 2008. LGL Report EA1986. Unpublished report by LGL Limited environmental research associates, Sidney, BC, for BC Hydro Generations, Water License Requirements, Castlegar, BC. 77 pp.

Hawkes, V.C., C. Houwers, J.D. Fenneman, and J.E. Muir. 2007. Kinbasket and Arrow Lakes reservoir revegetation management plan: Kinbasket Reservoir inventory of vegetation resources. Annual Report – 2007. LGL Report EA1986. Unpublished report by LGL Limited environmental research associates, Sidney, BC, for BC Hydro Generations, Water License Requirements, Burnaby, BC. 82 pp.

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

Hill, N.M., P.A. Keddy, and I.C. Wisheu. 1998. A hydrological model for predicting the effects of dams on the shoreline vegetation of lakes and reservoirs. Environmental Management, 22(5): 723–736

Hopfensperger, K.N. and K.A.M. Engelhardt. 2008. Annual species abundance in a tidal freshwater marsh: germination and survival across an elevational gradient. Wetlands 28: 521–526.

Hudon, C., 2004. Shift in wetland plant composition and biomass following low-level episodes in the St. Lawrence River: looking into the future. Canadian Journal of Fisheries and Aquatic Sciences 61: 603–617.

Ishii, J. and Y. Kadono. 2004. Sexual reproduction under fluctuating water levels in an amphibious plant *Schoenoplectus lineolatus* (Cyperaceae): a waiting strategy? Limnology 5: 1–6.

James, C.S., S.J. Capon, M.G. White, S.C. Rayburg, and M.C. Thoms. 2007. Spatial variability of the soil seed bank in a heterogeneous ephemeral wetland system in semi-arid Australia. Plant Ecology 190: 205–217.

Keddy, P.A. 1985. Wave disturbance on lakeshores and the within lake distribution of Ontario's Atlantic coastal plain flora. Canadian Journal of Botany, 63:656–660.

Kenow, K.P. and J.E. Lyon. 2009. Composition of the seedbank in drawdown areas of navigation pool 8 of the upper Mississippi River. River Research and Applications 25: 194–207.

Landis, J.R., and GG. Koch. 1977. The measurement of observer agreement for categorical data. Biometrics, 33: 159-174.

Legendre, P., and L. Legendre. 2012. Numerical Ecology, Third English Edition. Elsevier, 990p.

Lenssen, J.P.M. and H. De Kroon. 2005. Abiotic constraints at the upper boundaries of two Rumex species on a freshwater flooding gradient. Journal of Ecology 93: 138–147.

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

Luken, J.O. and T.N. Bezold. 2000. Plant communities associated with different shoreline elements at Cave Run Lake, Kentucky. Wetlands, 20: 479–486.

Luo, F.L., B. Zeng, T. Chen, X.Q. Ye, and D. Liu. 2007. Response to simulated flooding of photosynthesis and growth of riparian plant *Salix variegata* in the Three Gorges Reservoir region of China. Chinese Journal of Plant Ecology 2007: 910-918.

Maheshwari, B.L., K.F. Walker, and T.A. McMahon. 1995. Effects of regulation on the flow regime of the River Murray, Australia. Regulated Rivers: Research and Management 10: 15–38.

Mauchamp, A., Blanch, S., Grillas, P., 2001. Effects of submergence on the growth of *Phragmites australis* seedlings. Aquatic Botany 69: 147–164.

Mawhinney, W.A., 2003. Restoring biodiversity in the Gwydir Wetlands through environmental flows. Water Science and Technology 48: 73–81

Middleton, B.A. 2009. Regeneration potential of *Taxodium distichum* swamps and climate change. Plant Ecology 202: 257–274.

Moisen, G.G. 2008. Classification and regression trees, in Encyclopedia of Ecology, volume 1, p. 582-588.

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

Nicol, J.M., G.G. Ganf, and G.A. Pelton. 2003. Seed banks of a southern Australian wetland: the influence of water regime on the final floristic composition. Plant Ecology 168: 191–205.

Nilsson, C. and K. Berggren. 2004. Alterations of riparian ecosystems caused by river regulation. BioScience, 50: 783–792.

Nilsson, C. and P.A. Keddy. 1988. Predictability of change in shoreline vegetation in a hydroelectric reservoir, Northern Sweden. Canadian Journal of Fisheries and Aquatic Science, 45: 1896–1904.

Nilsson, C., C.A. Reidy, M. Dynesius, C. Revenga. 2005. Fragmentation and flow regulation of the world's large river systems. Science 308:405-408.

Nilsson; C. A. Ekblad, M. Gardfjell and B. Carlberg. 1991. Long-Term effects of river regulation on river margin vegetation. The Journal of Applied Ecology, 28: 963–987.

Nishihiro, J., S. Miyawaki, N. Fujiwara, I. Washitani. 2004. Regeneration failure of lakeshore plants under an artificially altered water regime. Ecological Research 19: 613–623.

Petts, G.E. 1979. Complex response of river channel morphology subsequent to reservoir construction. Progress in Physical Geography, 1: 329–362.

Poff, N.L. and J.K.H. Zimmerman. 2010. Ecological responses to altered flow regimes: a literature review to inform the science and management of regulated rivers. Freshwater Biology 55: 194–205.

R Development Core Team. 2007. R: A language and environment for statistical computing. R foundation for Statistical Computing, Vienna, Australia. Version 3.1.2; http://www.R-project.org

Raulings, E.J., K. Morris, M.C. Roache, and P.I. Boon. 2009. The importance of water regimes operating at small spatial scales for the diversity and structure of wetland vegetation. Freshwater Biology 55: 701–715.

Robertson, A.I., P. Bacon, and G. Heagney. 2001. The responses of floodplain primary production to flood frequency and timing. Journal of Applied Ecology 38: 126–136.

Robertson, H.A. and K.R. James. 2007. Plant establishment from the seed bank of a degraded floodplain wetland: a comparison of two alternative management scenarios. Plant Ecology 188: 145–164.

Roelle, J.E. and D.N. Gladwin. 1999. Establishment of woody riparian species from natural seedfall at a former gravel pit. Restoration Ecology, 7: 183–192.

Sim, J., and C.C. Wright. 2005. The Kappa statistic in reliability studies: use, interpretation, and sample size requirements. Physical Therapy, 85: 257-268.

Sorrell, B.K., Tanner, C.C., Sukias, J.P.S., 2002. Effects of water depth and substrate on growth and morphology of *Eleocharis sphacelata*: implications for culm support and internal gas transport. Aquatic Botany 73: 93–106.

Tabacchi, E. 1995. Structural variability and invasions of pioneer plant communities in riparian habitats of the middle Ardour River (SW France). Canadian Journal of Botany 73: 33–44.

Takagawa, S., J. Nishihiro, and I. Washitani. 2005. Safe sites for establishment of *Nymphoides peltata* seedlings for recovering the population from the soil seed bank. Ecological Research 20: 661–667.

Thomas, J.W. [Technical editor]. 1979. Wildlife habitats in managed forest of the Blue Mountains of Oregon and Washington. Agricultural Handbook No. 553, US Department of Agriculture Forest Service. 512 pp.

Van Geest, G.J., H. Coops, R.M.M. Roijackers, A.D. Buijse, and M. Scheffer. 2005. Succession of aquatic vegetation driven by reduced water-level fluctuations in floodplain lakes. Journal of Applied Ecology, 42: 251 – 260.

Vervuren, P.J.A., S.W.P.M Blom, H. De Kroon. 2003. Extreme flooding events on the Rhine and the survival and distribution of riparian plant species. Journal of Ecology 91: 135-146.

Wang, Q. X. Yuan, H. Liu, Y. Shang, Z. Cheng, and B. Li. 2012. Effects of long-term winter flooding on the vascular flora in the drawdown area of the Three Gorges Reservoir, China

Warwick, N.W.M. and M.A. Brock. 2003. Plant reproduction in temporary wetlands: the effects of seasonal timing, depth, and duration of flooding. Aquatic Botany 77: 153–167.

Watt, S.C.L., E. Garcia-Berthou, and L. Vilar. 2007. The influence of water level and salinity on plant assemblages of a seasonally flooded Mediterranean wetland. Plant Ecology 189: 71–85.

Wilcox, D.A. and S.J. Nichols. 2008. The effects of water-level fluctuations on vegetation in a Lake Huron wetland. Wetlands 28: 487–501.

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

Ye, C., K. Zhang, Q. Deng, and Q. Zhang. 2012a. Plant communities in relation to flooding and soil characteristics in the water level fluctuation zone of the Three

Gorges Reservoir, China. Environmental Science and Pollution Research. DOI: 10.1007/s11356-012-1148-x

Ye, C., X. Cheng, Y. Zhang, Z. Wang, and Q. Zhang. 2012b. Soil nitrogen dynamics following short-term revegetation in the water level fluctuation zone of the Three Gorges Reservoir, China. Ecological Engineering 38: 37-44.

Zhao CM, W.L. Chen, H.D. Huang, Z.Q. Tian, Y. Chen, and Z.Q. Xie. 2007. Spatial pattern of plant species diversity in the inundation and resettlement region of the Three Gorges Reservoir. Biodiversity Science 15: 510–522.

10.0 APPENDICES

Appendix 10-A. Example of data card used to record vegetation and associated site-specific information along transects sampled in 2014

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	