Columbia River Project Water Use Plan

Kinbasket and Arrow Reservoirs Revegetation Management Plan

Kinbasket Inventory of Vegetation Resources

Implementation Year 6

Reference: CLBMON-10

Final Report

Study Period: 2016

LGL Limited environmental research associates
Sidney, BC

March 1, 2017

EA3532

KINBASKET AND ARROW LAKES RESERVOIRS

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




Year 6 – 2016
Final Report

BC Hydro

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
Squamish, BC

March 1, 2017

LGL LIMITED
environmental research associates

Suggested Citation

Hawkes, V.C and P. Gibeau. 2017. CLBMON-10 Kinbasket Reservoir Inventory of Vegetation Resources. Annual Report–2016. LGL Report EA3532D. Unpublished report by LGL Limited environmental research associates, Sidney, B.C., for BC Hydro Generations, Water License Requirements, Burnaby, B.C. 62 pp + Appendices.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

2016 marked the sixth 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 and monitored in the drawdown zone of the reservoir. The distribution and extent of those communities have varied, but over time there has been a slight (~ 6 per cent) increase in the total extent of vegetation in the drawdown zone, which is related (in part) to the reduction in wood debris in the drawdown zone (from ~ 254 ha in 2007 to ~ 56 ha in 2016). This slight increase is coupled with a decrease in species richness over time. 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 2016 revealed some interesting patterns in species richness, diversity, and spatial extent:

Species Richness and Diversity

- Species richness and diversity increase with elevation;
- Species richness and diversity increase with increasing organic matter;
- Species richness and diversity are positively correlated with an increase in growing degree days (GDDs) in August;
- Species richness increases with increasing number of GDDs in May and September;
- Species richness varies by landscape unit (no discernable patterns);
- Species richness and diversity have decreased with time (years);
- Species richness and diversity decrease as slope increases; and
- Species richness and diversity decreases when reservoir elevations are high in September (deep water).

Spatial Extent of Vegetation

- The total spatial extent of vegetation increased (slightly) with time;
- Spatial extent of vegetation increased with high water in September;
- The spatial extent of vegetation varied relative to vegetation community;

- Spatial extent of vegetation was lower when GDDs were lower in May, June, July, and August; and
- Spatial extent of vegetation decreased with increasing water depth in July.

While the strength of some of these results is weak (the confidence intervals overlap slightly with 0; e.g., changes in species richness relative to the per cent ground cover of organics and cover of shrubs) they provide an indication of the variables that are responsible for the changes observed in vegetation community composition (i.e., richness) and total area over time. They also emphasize some of the variables that may be important when considering how to ensure vegetation communities persist in the drawdown zone. For example, areas with higher organic content tend to have higher species richness and when reservoir elevations are lower (i.e., water depth is lower), the number of GDDs increases and species richness and spatial extent tend to increase, suggesting that modification to reservoir operations would contribute to increases in the spatial extent and richness of vegetation growing in the drawdown zone of Kinbasket Reservoir.

Since 2007, the tendency has been to fill Kinbasket Reservoir earlier in the growing season and maintain higher elevations for longer into the year. This type of operation, coupled with an increased frequency of filling or surcharging the reservoir will likely result in a further reduction in species richness and diversity in communities situated in the upper elevation bands of the drawdown zone (i.e., those > 748 m ASL). The communities situated in the lower and mid elevation bands (i.e., < 748 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 (Figure 4-2). 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 at elevations >748 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. However, with successive years of non-filling events (i.e., 2015 and 2016), there is evidence that several species, including herbs, grasses, and more importantly, woody stemmed species of willow and cottonwood are establishing on ground that would normally be inundated in the fall (September). These patterns of colonization are consistent with the results CLBMON-10 and the effects of reservoir inundation on plant establishment vegetation community development. A reduction in the frequency, timing, duration, and depth of inundation will contribute to an increase in the cover and extent of vegetation in the drawdown zone Kinbasket Reservoir with the biggest changes occurring at higher elevations (>750 m ASL), on organic and mineral soils, and in areas devoid of wood debris.

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. Furthermore, it will likely be necessary to implement annual sampling that occurs, when possible, before and after inundation to determine if reservoir inundation effects plants growing at different elevations differently.

This could occur over a one or two year period with the data collected augmenting what was collected under CLBMON-10 between 2007 and 2016 so would provide a direct measure of the effects of the timing, duration, and depth of inundation on vegetation communities in Kinbasket Reservoir. Some of these questions may also be partially addressed by other programs such as CLBMON-35 and CLBMON-9

The status of CLBMON-10 after 2016 with respect to the management questions and management hypotheses are summarized in tabular form (below).

Management Question	Will MQ Be Addressed in 2016?	Current Supporting Results	Suggested Modifications to Methods Where Applicable	Sources of Uncertainty/ Limitations
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, 2014 and 21 in 2016 (DI = Disturbed was included due to the prevalence of this VCC in some areas) and the SW or Shrub-willow at higher elevations where transitional habitats exist between drawdown graminoid-dominated vegetation to upland forest. All analyses were based on the 19 communities described in 2010.	Not all areas of the draw down zone with existing vegetation have been mapped, which may underestimate the total area of existing vegetation. It may also underestimate the number of vegetation communities that occur in the draw down zone. If future work is considered for existing vegetation in the drawdown zone of Kinbasket Reservoir, these additional areas could be included. The results as presented in this report are unlikely to change as a result of mapping the extent of vegetation throughout the entire draw down zone of Kinbasket Reservoir.	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	The 19 communities characterized in 2010 have monitored and the distribution of those communities relative to elevation has been described. The spatial extent is affected by reservoir operations, particularly when the reservoir exceeds full pool. Various factors interact (depth, duration, timing, GDDs, wood debris accumulation) to influence vegetation communities occurring in the drawdown zone between 741 and 754 m ASL. Specifically, species richness, diversity, and spatial extent vary relative to one or more of the factors mentioned previously.	Not all areas of the draw down zone with existing vegetation have been mapped, which may underestimate the total area of existing vegetation. It may also underestimate the number of vegetation communities that occur in the draw down zone. If future work is considered for existing vegetation in the drawdown zone of Kinbasket Reservoir, these additional areas could be included. The results as presented in this report are unlikely to change as a result of mapping the extent of vegetation throughout the entire draw down zone of Kinbasket Reservoir.	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	Spatial extent varies relative to factors such as vegetation community, year, growing degree days (GDD), and water depth. Spatial extent varied significantly between communities within nine communities (WS, WB, TP, SH, RC, MA, LL, KS, CH) showing a significant increase in spatial extent while four (MC, FO, DR, and CT) showed a decrease. While taking all factors into account, the spatial extent of vegetation communities in general was positively correlated with year. The spatial extent of communities also varied with the amount of growing degree days and water depth: spatial extent decreased with GDD in June and July. Notably, spatial extent decreased with increasing water depth in July, but increased with increasing water depth in September.	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. This is because vegetation grows slowly and the duration of CLBMON-10 may not have been long enough to measure the response of vegetation to specific types of reservoir operations, specifically surcharge, which occurred in 2012 and 2013.	The longer-term effects of surcharge or repeated years of high water are likely to limit the spatial extent of existing vegetation communities. A within-year, pre- vs. post-assessment of the effects of inundation on vegetation could provide data to test this assumption. Data analyses completed under CLBMON-35 could also contribute to this assessment. The LiDAR data collected in 2014 has not been used to assess the timing, duration, frequency, and depth of Kinbasket Reservoir on existing vegetation. Given that we know the LiDAR data varies substantially from the DEM used in the assessment for CLBMON-10, it is recommended that the extent of vegetation communities and the effects of reservoir operations to those communities be reassessed relative to the LiDAR data.

Management Question	Will MQ Be Addressed in 2016?	Current Supporting Results	Suggested Modifications to Methods Where Applicable	Sources of Uncertainty/ Limitations
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. Over time, there has been a six per cent increase in the spatial extent of vegetation (all landscape units and VCCs combined), and this may be related to the removal of wood debris, which has exposed some areas of the drawdown zone and contributed to the establishment of vegetation. There is substantial variation in the spatial extent of vegetation within each vegetation community. The vegetation community classifications generated in 2007 have remained relatively stable over time, with little change in species composition of each community (i.e., the same dominant species can be used to define each community). The vegetation communities do partition along a gradient that is more related to successional status than species composition, with pioneering and young seral communities (e.g., LL, TP, CH) clustering together over time relative to mature seral to mature climax communities (e.g., CT, LH, and MC). The persistent partitioning of communities along a successional gradient suggests that the conditions these communities are subjected to are not conducive to succession. Although not all years and communities group together, this should not be taken as an indication that the initial classification (from 2007) was deficient; it is a reflection of the conditions under which the vegetation communities persist, which is evident with the results presented in this report.	See above - the longer term effects of the operating regime on the spatial extent of existing vegetation communities may not be realized over a 10 year period due to the relatively slow rates of vegetation succession. The predictable, yet variable manner in which Kinbasket Reservoir is managed (operating regime presents some challenges due to different operations from one year to the next. Additional sampling (within year, pre- vs. post-inundation over a one or two year period) coupled with more detailed analyses associated with CLBMON-35 will likely provide more insight into the relationships between reservoir operations and the spatial extent and species composition of exiting vegetation communities in the drawdown zone of Kinbasket Reservoir.	At present it appears that most communities are persisting in the drawdown. 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. The impacts of other non-measured factors such as rates of erosion and sedimentation related to reservoir operations and the effect on existing vegetation requires study. Similarly, the effects of wave energy (fetch, wave action) on the drawdown zone at different elevations have not been studied. The relationship between wood debris accumulation and scour has been reported, but not directly studied. We know that removing wood from the drawdown zone provides an opportunity for vegetation to naturally establish and develop, but not knowing the probability of wood debris accumulation or the mechanisms responsible for the inputs of wood into the system contributes to uncertainty regarding how the operating regime of Kinbasket Reservoir affects the spatial extent and species composition of exiting vegetation communities in the drawdown zone. We also know that there are elements of the natural environment that are likely to influence vegetation growing in the drawdown zone and that are not related to reservoir operations (e.g., debris flows, avalanches, and fire). Other influences (e.g., erosion, sedimentation, wood debris deposition, and wave energy) are related to reservoir operations, but the relative effect of these natural and reservoir-related factors were not studied under CLBMON-10. Some (e.g., wood debris deposition and perhaps erosion in some

Management Question	Will MQ Be Addressed in 2016?	Current Supporting Results	Suggested Modifications to Methods Where Applicable	Sources of Uncertainty/ Limitations
				places) could be assessed under CLBMON-35 or through a review of the CLBMON-10 and associated data with an aim to address as many of these uncertainties as possible.
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 on the reduction of factors such as GDDs, which affects the specie richness, diversity and spatial extent of vegetation in the drawdown zone, a reduction in the maximum elevation and duration of inundation would function to maintain and possibly expand existing vegetation at higher elevations (i.e., those >748 m ASL). 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. A trial was implemented via CLBWORKS-1 in 2015 and additional works are under consideration. These efforts are small-scale projects that will not result in the revegetation of large areas (10's or even 100's of hectares) of the drawdown zone.	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 < 748 to afford the vegetation at higher elevations time to develop. The current operation of the reservoir will probably contribute to a further reduction in species richness and may affect the spatial extent of vegetation over time.

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 Mark Sherrington, Guy Martel, Margo Sadler, of BC Hydro, Carrie Nadeau of Associated Environmental and Dave Polster of Polster Environmental. Dr. Michael Miller, Jamie Fenneman and Jeremy Gatten (LGL) collected field data. Terra Remote Sensing acquired the digital aerial imagery and produced the orthorectified imagery in 2016. 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. Naira Johnston (LGL) assisted with report preparation. HNZ Topflight (Penticton BC) provided helicopter services in 2016.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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 culminates 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 micro-topographic 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 of a 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 was 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.

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)
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).

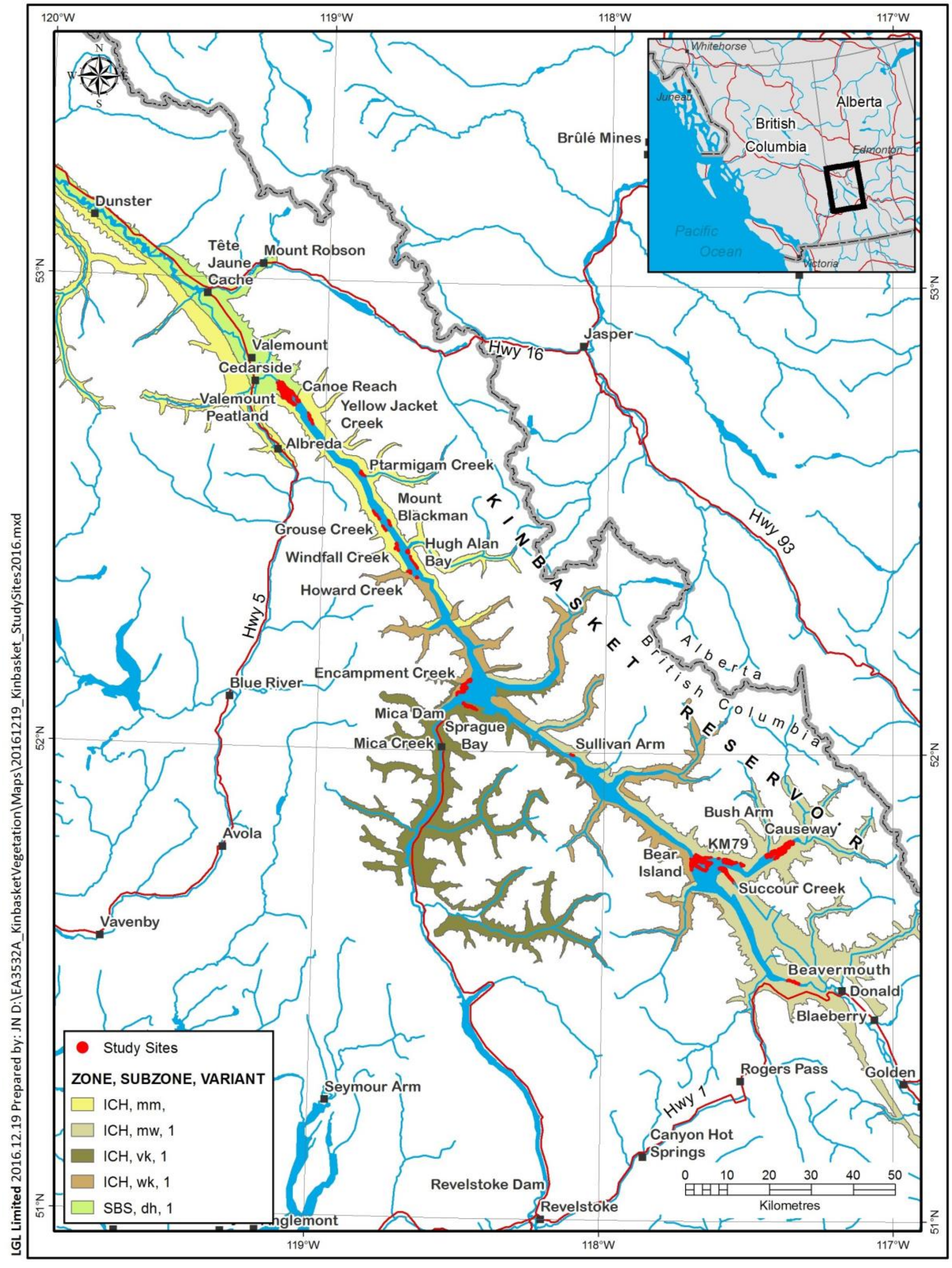

Figure 3-1: Location of Kinbasket Reservoir and vegetation sampling locations (red). Landscape unit names (e.g., Beavermouth, Encampment Creek) were assigned to each area sampled in 2007. Red areas also denote the locations of aerial photograph acquisition

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) and Hawkes and Gibeau (2015). The study is a longer-term monitoring program, spanning a period of ten years (2007–2016). During years 1, 2, 4, 6, 8, and 10 (2016), aerial photograph interpretation and field sampling were 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 were 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, visible in the aerial photography, that are delineated as vegetation communities. 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 10.1.2 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 were made. The baseline population was 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 various 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, 6, 8, and 10 (2007, 2008, 2010, 2012, 2014, and 2016). 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), Hawkes et al. (2013), and Hawkes and Gibeau (2015). A brief overview of 2007, 2008, 2010, 2012, and 2014 is provided in Section 10.1. Field methods followed those of Hawkes *et al.* (2007), Hawkes and Muir (2008), and Hawkes et al. (2010 and 2013) and Hawkes and Gibeau (2015). 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 2016 were of previously established transects. 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. A more detailed account of 2016 (Year 10) follows.

4.3 Year 10 (Sampling Year 6) – 2016

4.3.1 Vegetation Community Classification

Vegetation communities were defined in 2007 and included 16 vegetated and 2 non-vegetated types. These same 18 communities have been retained over time with the addition of a single community (the RD, or Common Reed community) in 2010 (Table 4-1). In 2014 two additional communities (not included in Table 4-1 as they are not being monitored) were added: the DI (Disturbed) and SW (Shrub-Willow) communities. Only the 19 communities classified in 2010 for the drawdown zone of Kinbasket Reservoir have been monitored for CLBMON-10 and are the focus of most analyses. The vegetation community codes in Table 4-1 are used throughout this document. Only two communities, the Buckbean-Slender Sedge (BS) and the Swamp Horsetail association (SH) have been previously described by Mackenzie and Moran (2004; Hawkes et al. 2007). The other 18 communities defined do not fit within established ecosystem site series or classes described in the regional field guides for forest classification, *A Field Guide for Site Identification and Interpretation for the Nelson Forest Region* (Braumandl and Curran 1992) and *A Field Guide for Site Identification and Interpretation for the Rocky Mountain Trench Portion of the Prince George Forest Region* (Meidinger et al. 1998; Meidinger 2007), nor do they fit within the nonforested ecosystem classification described in the *Wetlands of BC* (Mackenzie and Moran 2004). As such, novel community names were derived.

Table 4-1: List of the 19 vegetation communities classified for the 13 m drawdown zone of Kinbasket Reservoir (741m to 754 m ASL). Note that only the BS and SH communities align with site series classifications used in BC (Mackenzie and Moran 2004); the remainder are unique to the drawdown zone of Kinbasket Reservoir.

No.	Code	Common Name	Scientific Name	Drainage	Typical Location
1	**LL**	Lady's thumb - Lamb's quarter	*Polygynum persicaria - Chenopodium album*	imperfectly to mod well	lowest vegetated elevations
2	**CH**	Common Horsetail	*Equisetum arvense*	Well	above LL or lower elevation on sandy, well-drained soil
3	**TP**	Toad rush - Pond water-starwort	*Juncus bufonius - Callitriche stagnalis*	imperfectly	above LL, wet sites
4	**KS**	Kellogg's sedge	*Carex lenticularis* spp. *licocarpa*	imperfectly to mod well	above CH
5	**BR**	Bluejoint reedgrass	*Calamagrostis canadensis*	mod well	above CH, often above KS
6	**MA**	Marsh cudweed - Annual Hairgrass	*Gnaphalium uliginosum - Deschampsia danthonioides*	imperfectly-mod well	common in the Bush Arm area
7	**RC**	Canary Reedgrass	*Phalaris arundinacea*	imperfectly to mod well	similar elevation to CO community
8	**RD**	Common Reed	*Phragmites australis*	poor	Above BR and below CO
9	**CO**	Clover - Oxeye daisy	*Trifolium* spp. - *Leucanthemum vulgare*	well	typical just below shrub line and above KS
10	**CT**	Cottonwood - Clover	*Populus balsamifera* spp. *trichocarpa-Trifolium* spp	imperfectly to well drained	above CO, below MC and LH
11	**MC**	Mixed Conifer	*Pinus monticola, Pseudotsuga menziesii, Picea engelmanni X glauca, Tsuga heterophyla, Thuja plicata*	Well	above CT along forest edge
12	**LH**	Lodgepole Pine - Annual hawksbeard	*Pinus contorta - Crepis tectorum*	well to rapid	above CT along forest edge, very dry site
13	**BS**	Buckbean - Slender sedge	*Menyanthes trifoliata-Carex lasiocarpa-Scirpus atrocintus, S microcarpus*	Very poor to poor	wetland association
14	**WB**	Woolgrass-Pennsylvania Buttercup	*Scirpus atrocinctus - Ranunculus pensylvanicus*	imperfectly to poor	wetland association
15	**SH**	Swamp horsetail association	*Equisetum variegatum,E fluviatile, E palustre*	poor	wetland association
16	**WS**	Willow - Sedge wetland	*Salix - Carex* species	Very poor to poor	wetland association
17	**DR**	Driftwood	Long linear bands of driftwood, very little vegetation	n/a	whole logs and large pieces of logs without bark
18	**WD**	Wood Debris	Thick layers of wood debris, no vegetation	n/a	typically small pieces similar to bark mulch
19	**FO**	Unclassified Forest	Any forested community	n/a	Above drawdown zone (>756 m ASL)

Vegetation Communities – Successional Status 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 status theory (Thomas 1979; Bunnell *et al.* 1999) and used the successional status definitions in BC Ministry of Forest and Range and BC Ministry of Environment (2010). Successional status describes a temporal stage in a pathway of plant community development that is characteristic for a particular environment (BC Ministry of Forest and Range and BC Ministry of Environment 2010).

In general, Pioneer Seral and Young 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 (Table 4-2). In most cases, wetland or wetland-associated communities are included among the Mature Seral to Young or Mature Climax[4] communities. Communities that contain tree species are considered Maturing 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. In the absence of inundation, non-wetland habitats would likely trend toward tree-dominated communities. The classification of vegetation communities into a drawdown successional status did not consider the non-vegetated communities or those that occur outside of the drawdown zone (e.g., the DR, WD, of FO communities).

Table 4-2: Proposed successional status of the 15 vegetation communities (VCC) delineated in the drawdown zone of Kinbasket Reservoir. Successional status follows BC Ministry of Forest and Range and BC Ministry of Environment (2010). Note that non-vegetated (DR and WD) comminutes and the forest (FO) community are not listed.

VCC	Name	Successional Status
LL	Lady's thumb-Lamb's quarter	Pioneer Seral
CH	Common Horsetail	Pioneer Seral
TP	Toad Rush - Pond Water-starwort	Young Seral
MA	Marsh Cudweed - Annual Hairgrass	Young Seral
KS	Kellogg's Sedge	Young-Mature Seral
BR	Bluejoint Reedgrass	Mature Seral
RD	Common Reed	Mature Seral – Young Climax
CO	Clover - Oxeye Daisy	Mature Seral – Young Climax
WB	Wool-grass - Pennsylvania Buttercup	Mature Seral – Young Climax
SH	Swamp Horsetails	Maturing Climax
BS	Buckbean - Slender Sedge	Maturing Climax
WS	Willow - Sedge wetland	Maturing Climax
CT	Cottonwood - Trifolium	Maturing Climax
LH	Lodgepole Pine - Annual hawks beard	Maturing Climax

[4] The concept of climax is a theoretical state and note necessarily one that is easily (or ever) observed. In this case, some vegetation communities growing in the drawdown zone will reach a steady state (as per the historical definition of a climax community) based on the fact that the vegetation in those communities is best adapted to the current environment.

MC	Mixed Conifer	Maturing Climax

4.3.2 2016 Sampling Objectives

The objectives of the 2016 field sampling were to resample transects established in previous year in each vegetation community. Field sampling was used to verify whether vegetation communities have changed over time. Field data were also used to verify the delineation of vegetation community polygons on the aerial photos obtained in 2016.

4.3.3 Field Sampling: Timing

Field sessions were timed to correspond with sampling in previous years (Table 4-3) and to ensure that all (or the majority) of planned sampling occurred prior to inundation. A hydrograph of Kinbasket Reservoir is provided in Figure 4-1 illustrating the variation in reservoir management among years of sampling associated with CLMBON-10 while Figure 4-2 provides a summary of the range of reservoir operations in Kinbasket between 1976 and 2016.

Table 4-3: Field survey dates for each field work period and reservoir elevations in each year of sampling associated with CLBMON-10 in Kinbasket Reservoir.

	Field Work 1		Res. Elev. (mASL)		Field Work 2		Res. Elev. (mASL)	
Year	**Start**	**End**	**Min**	**Max**	**Start**	**End**	**Min**	**Max**
2007	26-Jun	29-Jun	742.48	743.47	10-Jul	18-Jul	747.54	750.41
2008	15-Jun	25-Jun	732.30	735.71	11-Jul	25-Jul	742.88	745.98
2010	14-Jun	23-Jun	732.54	735.69	12-Jul	26-Jul	750.23	751.52
2012	11-Jun	21-Jun	733.93	738.86	16-Jul	26-Jul	752.29	754.30
2014	18-Jun	29-Jun	738.23	742.79	11-Jul	22-Jul	747.15	750.29
2016	17-Jun	27-Jun	745.75	747.21	08-Jul	16-Jul	749.02	750.20

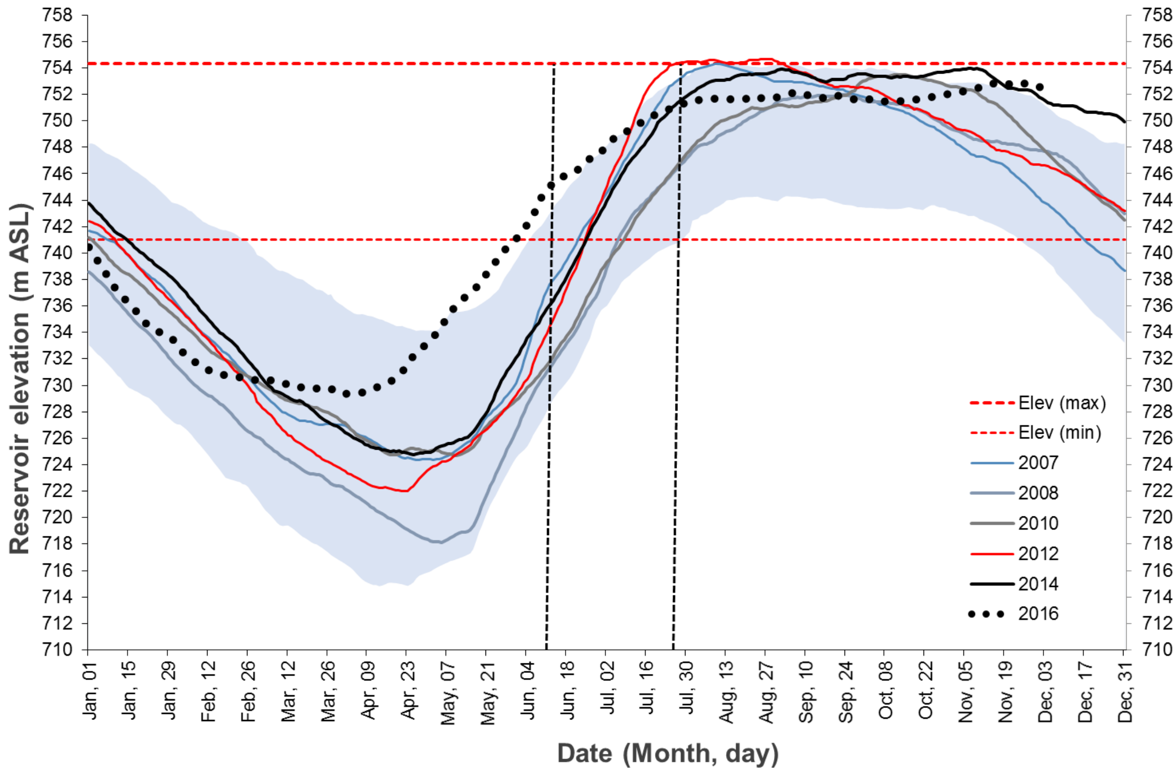

Figure 4-1: Kinbasket Reservoir elevations (m ASL) in 2007, 2008, 2010, 2012, 2014 and to December 6, 2016. The shaded area indicates the 10th and 90th percentile (1976 to 2016). The 754 m and 741 m ASL elevations are indicated (red dashed horizontal line). Vertical black dashed lines represented the min and max date of sampling (all years)

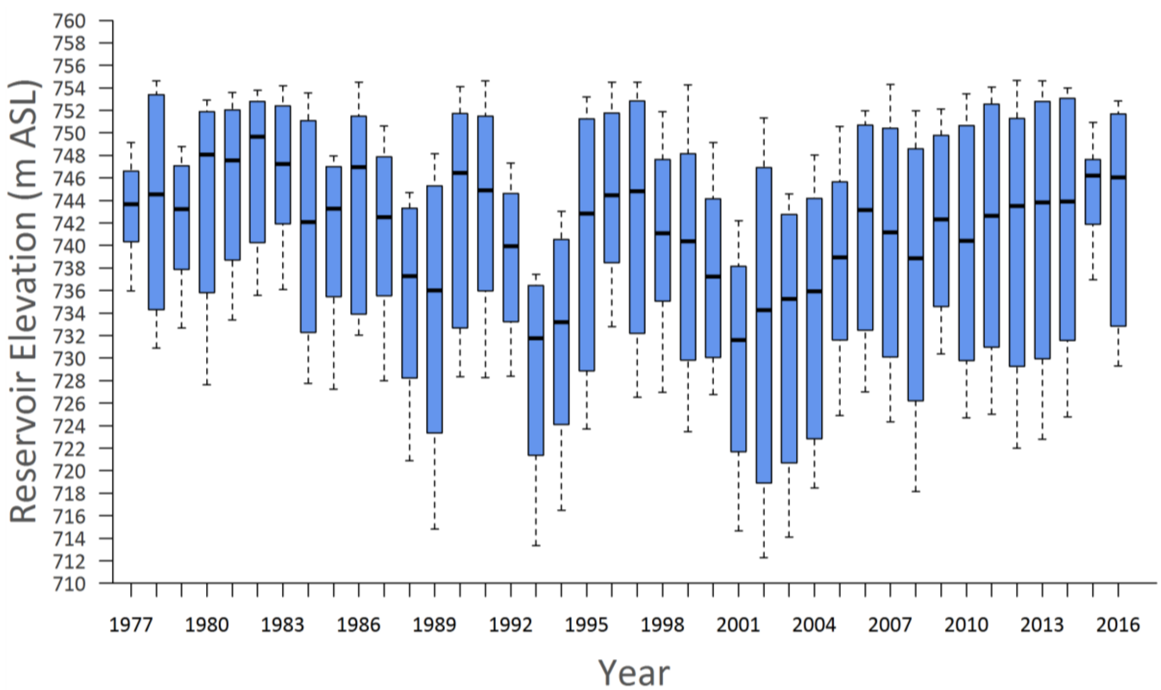

Figure 4-2: Annual variation in Kinbasket Reservoir elevations between 1976 and 2016

Sampling locations were predetermined in the office using GIS and were selected to ensure that all landscape units and vegetation communities sampled in previous years were resampled. In 2016, 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 75 of the 108 transects were sampled. Fifteen of the 19 vegetation communities were sampled in 2016. Of these, sampling in the Unclassified Forest (FO), Mixed Conifer (MC), RC (Canary Reedgrass) was not planned due to the location of the community (at elevations > 754.38 m ASL; FO) or due to the small size or location of the community in the drawdown zone (which made it difficult to sample; RC and MC). Of the remaining vegetation communities, only the Toad rush – Pond water-starwort (TP) community was not sampled in 2016 due to reservoir elevations that precluded sampling at low elevations where this community occurs.

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.

4.3.4 Plant Identification

Botanical nomenclature followed that of the current BC provincial flora checklist (MacKenzie et al. 2016). To speed data entry, the accepted 7 or 8 character code (from the same provincial checklist) was used for recording plant names on the field form. Plants that could not be identified immediately in the field were collected for later identification. Collections were recorded as such on the field form and species names later filled in. Where specimens could not be identified to species, the genus or family name was noted. Field personnel were constant across all years of study.

4.3.5 Aerial Photo Acquisition and Interpretation

Aerial photographs of select areas of the drawdown zone [areas identified as having high or medium potential for vegetation enhancement (Moody and Carr 2003)} were acquired in 2007, 2008, 2010, 2012, 2014, and 2016. In most years the aerial photographs covered a larger area than was required by the study (i.e., elevations <741 m and >754 m ASL). However, due to environmental condition or rapidly increasing reservoir elevations, this was not always the case (e.g., 2008, 2016; Table 4-4). In 2007 and 2008, aerial photographs were captured using analog cameras. In 2010, photos were captured digitally by Terrasaurus Aerial Photography Ltd. Aerial photos and associated LiDAR data were provided by Terra Remote Sensing in 2014 and 2016.In 2016 most aerial photos were acquired between 5 and 8 June when the elevation of Kinbasket Reservoir varied from 742.47 m to 749.02 m ASL. The upper elevations (i.e., those areas > 750 m ASL) of certain areas of the drawdown zone (e.g., Canoe Reach) were captured on 22 June 2016.

Table 4-4: Photo acquisition dates and reservoir elevations for Kinbasket Reservoir in each year of study. The target elevation range was 741 to 754 m ASL

	Photo Acquisition		Res Elev. (mASL)	
Year	Start	End	min	max

2007	30-May	31-May	729.79	730.16
2008	25-Jul	.	745.76	.
2010	16-Jun	18-Jun	733.19	733.76
2012	22-Jun	28-Jun	739.39	743.01
2014	20-Jun	21-Jun	739.10	739.51
2016	5-Jun	22-Jun	742.47	750.71

4.3.6 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). This approach was used again in 2016, with 2014 polygons updated to the 2016 imagery etc.

4.4 Variables Estimated, Data Summaries, and Statistical Analyses

Most data summaries and statistical analyses methods follow Hawkes et al. (2013) and Hawkes and Gibeau (2015). Only new methods as used in 2016 are summarized below.

4.4.1 Transect Data

As in previous years, 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, and diversity were computed and processed in the same ways as previously reported in 2012 (Hawkes et al. 2013) and 2014 (Hawkes and Gibeau 2015) except that trends were based on five years of data (i.e., 2007, 2010, 2012, 2014, and 2016); data from 2008 were excluded from analyses for reasons explained in the 2010 annual report (Hawkes *et al.* 2010). The only new analysis that was added in 2016 was the computation of General Linear Mixed Models (GLMMs, Zuur et al. 2007). GLMMs were performed using the R package 'nlme' (v. 3.1-129, Pinherio 2017) in two cases; first, to perform repeated-measure analysis of variance (ANOVAs) assessing the significance of differences in general descriptors (richness and diversity) among vegetation communities, landscape units, and over time. Using GLMMs allowed explicitly considering the repeated nature of the data (i.e. the fact that sampling occurred in the same transects over time) by including transects as a random effect. The general form of the models in that case was:

Richness or Diversity ~ Landscape Units (or Vegetation Communities) * Year, random=~1| Transect

Second, GLMMs were used to look at variations in richness and diversity of vegetation in relation to landscape units and a series of environmental and climatic variables over time between 2007 and 2016. Two series of models were built: ones that included elevation as an explanatory variable, and ones that included growing degree days (GDDs) and average depth of inundation per month. Because GDDs and depth of inundation are derived from elevation, they could not be included in the same models. The other environmental variables included were: year, average cover of shrub, average cover of herb, average cover of live organic matter, average cover of decay wood, average cover of mineral soil, slope, heatload, landscape unit, and vegetation community. Water depth in April, May and June, and GDD in April were excluded from the analysis due to low variation in the data. Water depth in August was also omitted because it was highly collinear with depth in September. Vegetation communities DI, LH, RD, SW, and WD were excluded from the analysis because they did not have a sufficient number of replicates. Once again, the GLMMs included a random effect for transect to account for the repeated nature of the sampling in some transects over time. Diagnostic plots were reviewed to determine how the data aligned with basic fitting assumptions. Richness and diversity were log-transformed to ensure that models were fitted to a positive scale. Results presented only include significant variables and models that had the lowest Akaike information criterion (AIC). Coefficient plots were produced to interpret the results of the models. Coefficient plots show the value of the regression coefficients (effect size) for each explanatory variable, along with a measure of their variation (+- 2 standard error with confidence interval). The width of the confidence intervals indicate the precision of the estimated coefficients, and thus gives an indication of the confidence one can have in interpreting the sign and magnitude of the regression coefficient. Narrow confidence intervals means that regression coefficient are precise; confidence intervals that cross the 0 line mean a reduced confidence in the effect described by the coefficient; caution then has to be used to interpret its significance. Continuous explanatory variables were standardized prior to inclusion in the GLMM models as they were in different units and dimensions (Legendre and Legendre 2008). The significance of the GLMMs was provided via a wald test, which is an approximation of the likelihood ratio test that tests each coefficient against the full model containing all coefficients.

4.4.2 Polygon Data

Most analyses, tables, and figures applied to the polygon data were similar to those performed in 2014 (Hawkes and Gibeau 2015), except that again, five years (2007, 2010, 2012, 2014, and 2016) of data were included. The only new analysis performed in 2016 was the use of GLMMs to assess the relationship between spatial extent of vegetation and vegetation communities, growing degree days and average water depth per month, over time. GLMMs were done as described for the transect analyses (section 4.4.1).

4.4.3 Climatic Data

Meteorological data from two stations in the vicinity of Kinbasket Reservoir (Table 4-5) 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. The package openair v. 2.0.0 (Carslaw and Ropkins 2002) and the R language v. 3.3.2 was used to generate wind rose plots representing the predominant wind flow direction and speed in Kinbasket Reservoir.

Table 4-5: 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

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 accumulated on a daily basis over a period of time, which in the case was April 1 through September 30. Growing degree days (GDDs) are a measure of heat accumulation used to predict plant development rates The base temperature is the temperature below which plant growth is considered to be 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 gr

owth-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. The number of GDDs was corrected for reservoir inundation by reducing the GDDs for a given elevation band based on the date of inundation in each year.

5.0 RESULTS

5.1 Vegetation Data – Transects

Since 2007, 164 transects have been sampled in the drawdown zone of Kinbasket Reservoir. The number sampled per year ranged from 65 in 2012 to 97 in 2010. In 2016, a total of 73 transects were sampled, much fewer than planned owing to rapidly increasing reservoir elevations. The number of years in which a given transect was sampled ranges from one to five. Overall, four transects were sampled five times (i.e., in five of the six years of sampling because 2008 is excluded), 51 transects were sampled in four of six years, 37 in three of six, 10 in two of six and 62 transects were sampled in only one year. The number of transects sampled in five years was lower than planned due to a reduction in sampling in 2016.

5.1.1 Vegetation Community Classification

The vegetation data collected at each transect in each year was used to determine whether the species composition of those communities changed over time. The classifications generated in 2007 have remained relatively stable over time, with little change in species composition of each community (i.e., the same dominant species can be used to define each community). The vegetation communities do partition along a gradient that is more related to successional status than species composition, with pioneering and young seral communities (e.g., LL, TP, CH) clustering together over time relative to mature seral to mature climax communities (e.g., CT, LH, and MC; Figure 5-1). The persistent partitioning of communities along a successional gradient suggests that the conditions these communities are subjected to are not conducive to succession. Although not all years and communities group together in Figure 5-1, this should not be taken as an indication that the initial classification (from 2007) was deficient; it is a reflection of the conditions under which the vegetation communities persist, which will become evident with the proceeding results.

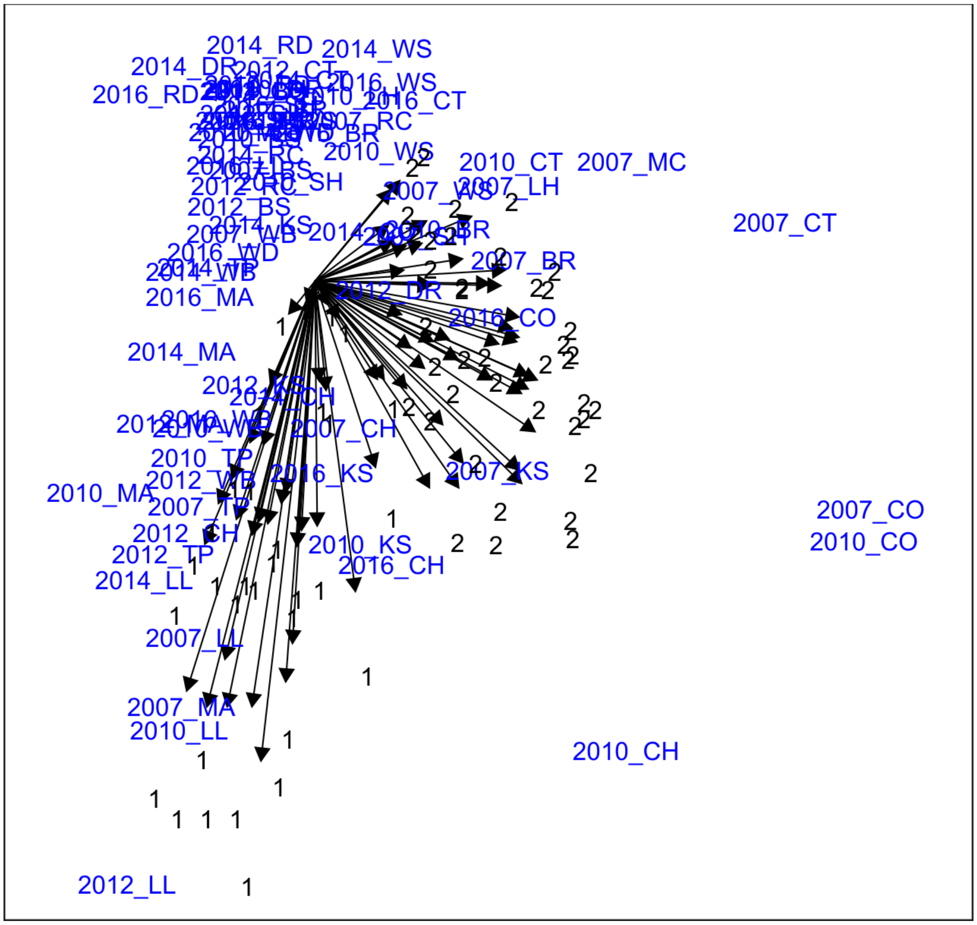

Figure 5-1: **Principal Components Analysis ordination diagram with superposition of the results of Kendall Concordance analysis (which was significant: W=0.014, F=1.55, p=0.00001).** Black vectors represent the average cover of the main vegetation species. Numbers represent the grouping of vegetation and species by successional status with 1 representing pioneering and young seral communities and 2 indicative of mature to maturing climax communities (see Table 4-2) Axis X expresses 17 per cent of the variation of the data set, and axis Y, 11 per cent. Community codes (in black) are expanded in Table 4-1.

5.1.2 Species Constancy

Since 2007, 291 species of vegetation have been recorded in the drawdown zone of Kinbasket Reservoir; however, excluding 2008, there were 274 species of vascular plants recorded in 2007, 2010, 2012, 2014, and 2016[5] (See Appendix 10.2, Figure 10-1). Of those species, 57 (21 per cent) were observed in all five years of sampling, 43 (16 per cent) were observed in four of the five years, 40 (14 percent) in three of five years, 44 (15 per cent) in two of five years, and 90 (33 per cent) were observed in only one year. A total of 199, 187, 89, 128, and 152 plant species were documented in 2007, 2010, 2012, 2014, and 2016 respectively. Differences in total numbers of plants per year can be partly

[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 photographed).

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 from 2010–2016, with between 3 and 21 unique species. More unique species were documented in 2007, which may be related to the fact that Kinbasket Reservoir had not been filled to the normal maximum elevation of 754.3.8 m ASL in the nine preceding years allowing for increased in-growth of vegetation, particularly at higher elevations (i.e., those > 751 m ASL).

Species constancy per transect (the number of times a species that occurred in 2016 was documented in at least one other year of sampling) ranged from 0 to 100 per cent (mean = 24 percent; SD = 21.5 per cent; n=55). Four of the 55 transects assessed had 0 per cent constancy, meaning that none of the species documented in 2016 were documented in any other year (these transects were located at Windfall Creek, Sullivan Arm, Grouse Creek, and Mount Blackman – all areas that have experienced substantive erosion and scour due to wood debris in previous years) while only two had 100 per cent constancy. While these two transects occur at higher elevations (751 and 752 m ASL), there is no relationship between elevation and per cent species constancy (Appendix 10.2, Figure 10-2, top). Species constancy relative to landscape unit (Appendix 10.2, Figure 10-2, bottom) was generally low, but trends are difficult to discern owing to small sample sizes.

Species constancy varied among vegetation communities (Table 5-1; Figure 5-2). The Clover-Oxeye Daisy (CO) community had the highest proportion of species recorded in the five years of sampling followed by the Lady's Thumb-Lamb's Quarter (LL) community and Willow–Sedge Wetland (WS) community (94, 91, and 90 per cent, respectively; Table 5-1). The Lodgepole Pine - Annual hawks beard (LH) and Driftwood (DR) communities had relatively low species constancy over time (25 and 50 per cent, respectively). It is not clear what contributes to high species constancy within a vegetation community, but topography and location in the drawdown are likely important. Elevation does not appear to be a factor as the vegetation communities with the highest (CO) and lowest (LH) per cent species constancy are both situated high in the drawdown zone (750 to 754 m ASL) while the LL community exists at elevations ranging from 742 to 750 m ASL.

Table 5-1: Species constancy within vegetation communities sampled in 2007, 2010, 2012, 2014, and 2016. Note: different numbers of transects were sampled per community in each year. Percent constancy was calculated as the proportion of all species present in 2016 that were recorded in at least one of the previous sample years. Communities were ordered according to seral stage, from pioneer seral to maturing climax. Refer to Table 4-1 for vegetation community definitions.

VCC	Number of species observed in…									# species in 2016	Total # of species (overall)	% constancy
	2007 only	2010 only	2012 only	2014 only	2016 only	2/5 years	3/5 years	4/5 years	All 5 years			
LL	4	9	1	4	1	9	7	9	8	11	53	91
CH	3	28	1	3	11	19	16	10	13	57	104	81
TP	9	3	1	1	0	4	3	17	--	--	38	--
MA	8	1	2	2	4	8	6	3	8	18	42	78
KS	19	4	2	6	13	22	13	15	22	64	116	80
BR	17	14	0	7	3	17	9	10	0	25	77	88
CO	48	13	0	4	4	36	23	24	3	64	155	94
WB	2	2	5	2	10	10	10	15	10	47	65	79
SH	26	6	0	3	3	11	6	7	6	18	68	83
BS	6	1	5	0	10	7	5	11	2	31	47	68
WS	18	13	1	4	6	24	15	19	10	58	110	90
CT	29	15	0	6	8	12	14	1	6	32	91	75
LH	13	3	--	--	3	1	1	--	--	4	21	25
DR	--	2	12	2	5	1	4	2	--	10	28	50

5.1.3 Unique and New Species

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 2016 appear more similar to 2014 and 2012 (with the exception of MA, KS, and WB) than to 2007 and 2010. The largest number of unique species (i.e., sampled in only one community in 2016) was associated with the Buckbean-Slender Sedge (BS) community followed by the Driftwood (DR) and the Marsh Cudweed – Annual Hairgrass (MA) communities (Figure 5-2). The lowest number of unique species was associated with the Toad Rush – Pond Water – Star Wart (TP) community, with no unique species. The high number of unique species in BS and DR may reflect its transitional position near the top of the drawdown zone. BS represents a structurally diverse composition of vegetation that includes a speciose willow and shrub assemblage not found at lower elevations.

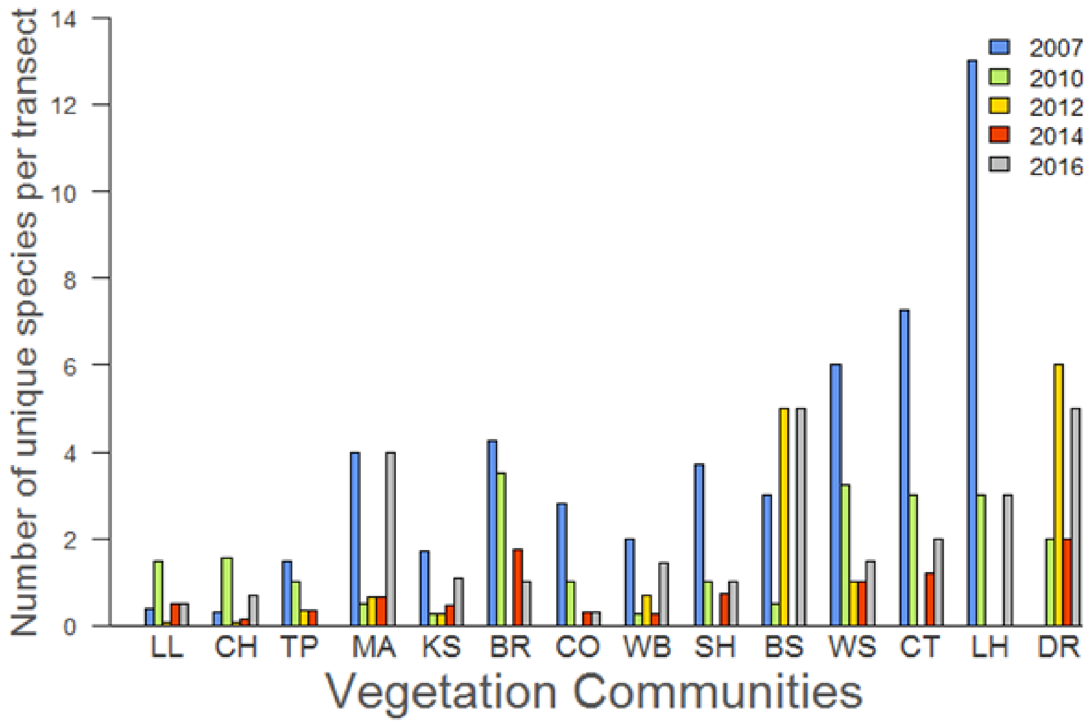

Figure 5-2: Number of species unique to a vegetation community over time, corrected for the number of transects sampled each year. Vegetation communities are ordered according to seral stage, from pioneering to late seral communities. Refer to Table 4-1 for vegetation community codes.

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. The three generalist species observed in almost all vegetation communities in all years were: Common Horsetail (*Equisetum arvense*), Bluejoint Reedgrass (*Calamagrostis Canadensis*), and Lakeshore Sedge (*Carex lenticularis*). In 2016 wool-grass (SCIRATR) was also one of the most generalist species. However, Bluejoint reedgrass (CALACAN), Norwegian Cinquefoil (POTENOR), White clover (TRIFREP), Grass sp. (POA), Fowl Bluegrass (POA PAL), Reed Canarygrass (PHALARU), Lady's-thumb (PERSMAC), Small Bedstraw (GALITRD), and European Forget-me-not (MYOSSCO) were also frequently encountered among years. A similar pattern has been reported in other reservoirs (Miller et al. 2015) and appears to be independent of the total species documented in a given year.

Most unique species associated with a given landscape unit (i.e., species observed in only one year by site) were recorded in Bush Arm (BSA), followed by Encampment Creek (Enc) and Canoe Reach (CNR; Figure 5-3, top). Most of the unique species across the landscape units were documented in 2007, 2010, and 2016. 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 sampling (Figure 5-3, bottom). Most of the new species recorded in 2016 were in Encampment Creek, Sprague Bay (Spr), Yellowjacket Creek (YJC) and Bush Arm, despite similar sampling effort as in previous years (i.e., similar number of transects sampled).

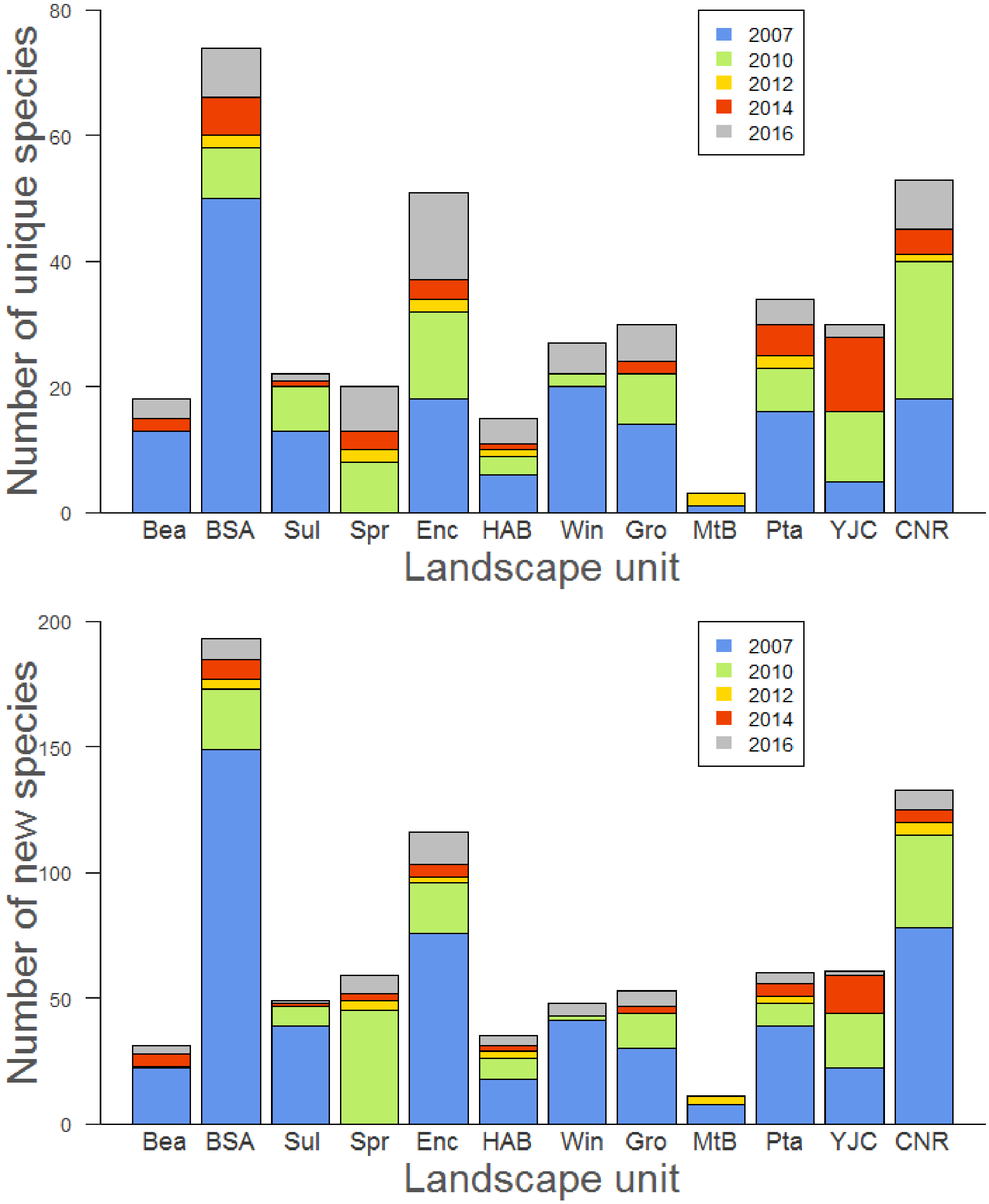

Figure 5-3: Number of unique species (top) and new species (bottom) recorded in each landscape unit over time (2007, 2010, 2012, 2014, and 2016; excluding mosses). Bea = Beaver Mouth, BSA = Bush rm; Sul = Sullivan Arm; Spr = Sprague Bay; Enc = Encampment Creek; HAB = Hugh Alan Bay; Win = Windfall Creek; Gro = Grouse Creek; MtB = Mount Blackman; Pta = Ptarmigan Creek; YJC = Yellowjacket Creek; CNR = Canoe Reach. Howard Creek was only sampled in 2007 and is not represented here. Sprague Bay was not sampled in 2007, and Beavermouth was not sampled in 2012. North of Grouse Creek is included within Grouse Creek. Landscape units are ordered from south to north in Kinbasket Reservoir.

5.1.4 Vegetation Communities and Elevation

The distribution of vegetation communities relative to elevation in the drawdown zone of Kinbasket Reservoir in 2007, 2010, 2012, 2014, and 2016 is shown in Figure 5-4. As previously reported (Hawkes *et al.* 2007, 2010, 2013, 2015), vegetation communities occur across a range of elevations that have been fairly consistent between years. However, an analysis of mean elevation over time indicated an increase in mean elevation for Clover-Oxeye daisy (CO), Driftwood (DR), Common Horsetail (CH), Unclassified Forest (FO) and Swamp horsetail association (SH) over time, and a decrease in mean elevation for Lady's thumb-Lamb's quarter (LL) and Toad rush – Pond water-starwort (TP) over time (Figure 5-4). In addition, both Toad rush – Pond water-starwort (TP) and Driftwood (DR) showed a significant change in elevation distribution; Toad rush–Pond water-starwort (TP) distribution was significantly lower in all years compared to 2007 (2010 t=-2.80, p=0.044; 2012 t=-2.83, p=0.40; 2014 t=-2.96, p=0.028; 2016 t=-2.93, p=0.031), whereas the Driftwood (DR) distribution was significantly higher in 2014 (t=3.14, p=0.016) and 2016 (t=2.88, p=0.034) compared to 2007. In general, 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.

Figure 5-4: Elevation range associated with each of the vegetation communities characterized in the drawdown zone of Kinbasket Reservoir in 2007, 2010, 2012, 2014, 2016. Refer to Table 4-1 for a description of the vegetation communities. Disturbed (DI) and Shrub Willow (SW) communities are not used in analyses

5.1.5 Species Richness and Diversity

Species richness varied among vegetation communities and over time (Figure 5-5). With the exception of a few vegetation communities, 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 2016. The notable outliers for high richness values include Wool-grass-Pennsylvania Buttercup (WB) communities in 2007, Marsh Cudweed-Annual Hairgrass (MA) in 2007 and 2016, Willow-Sedge Wetland (WS) in 2012, and Buckbean-Slender Sedge (BS) in 2012 and 2016 (Figure 5-5). 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.

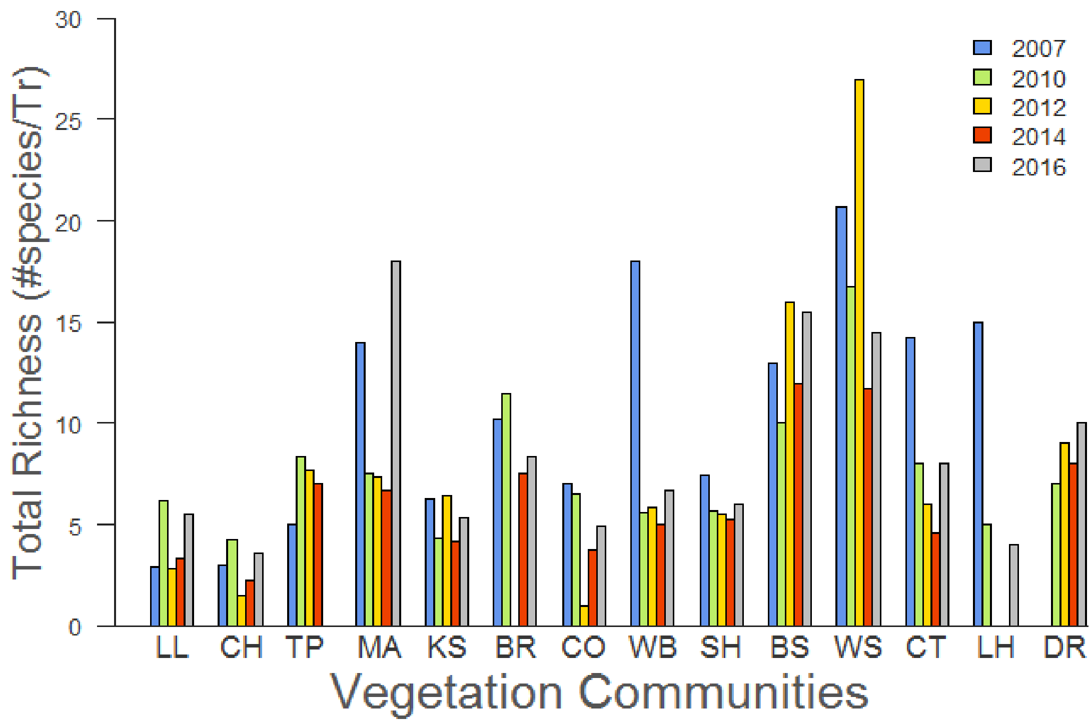

Figure 5-5: Total richness (number of species) per vegetation community in 2007, 2010, 2012, 2014, and 2016, corrected by the number of transects sampled in each year. Vegetation communities are ordered relative to seral stage, from pioneering to late seral communities. Refer to Table 4-1 for a description of the vegetation communities

Species richness varied among vegetation communities and across time within some (but not all) communities (Figure 5-6). Results from a Generalized Linear Mixed Model (GLMM) found that differences in species richness were statistically significant among years (F=23.2, p<0.0001) and between vegetation communities (F=6.5, p<0.0001). Interactions between year and VCC were not significant (F=1.3, p=0.25; VCCs tested were CH, CO, CT, KS, LL, SH, and WS; others not tested due to lack of replication).

Overall, changes in species richness have been variable overtime. For many vegetation communities [e.g., Lady's thumb-Lamb's quarter (LL), Toad rush–Pond water-starwort (TP), Bluejoint reedgrass (BR), and Buckbean–Slender sedge (BS)], species richness has decreased. For others, species richness has remained stable over time [Common Horsetail (CH) and Kellogg's Sedge (KS)], possibly consistent with them being an annual-dominated, ruderal community. For others, there are no apparent trends with respect to changes in species richness [e.g., Marsh cudweed–Annual Hairgrass (MA) and Willow–Sedge wetland (WS)], while others {(Clover–Oxeye Daisy (CO), and Cottonwood–Clover (CT)] appear to have recovered from a marked reduction in species richness associated with 2012, which may be indicative of the highly dynamic environment in which the vegetation communities persist.

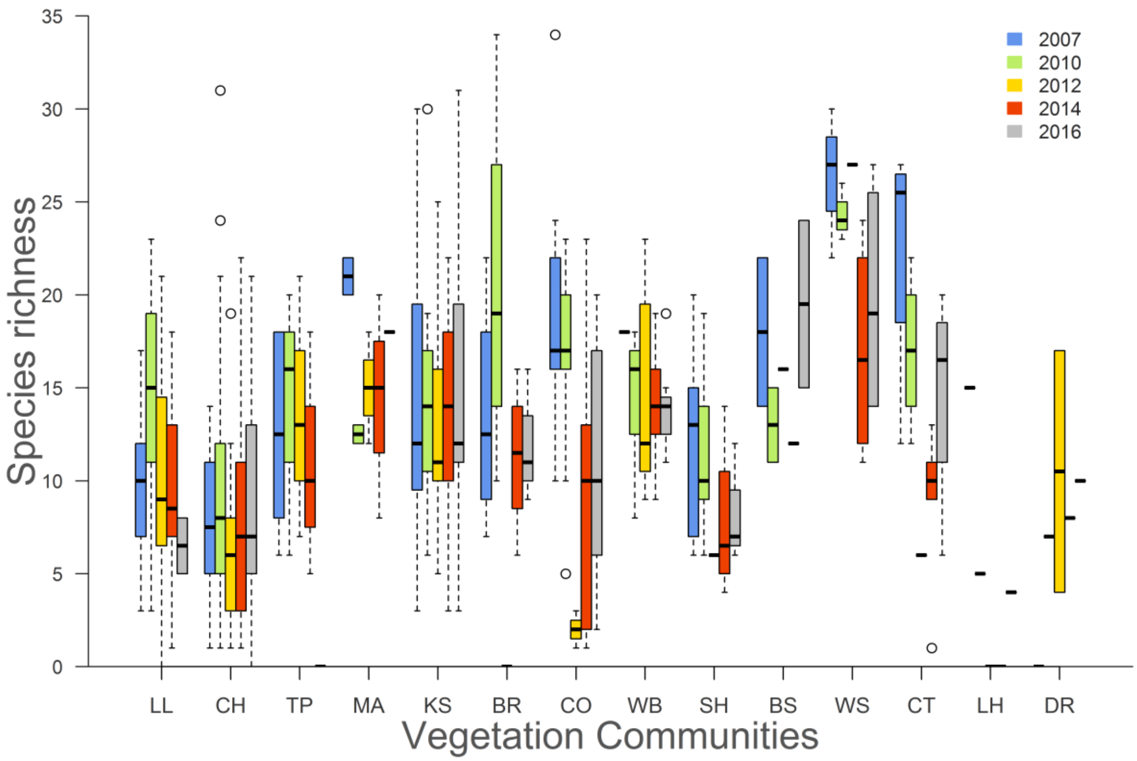

Figure 5-6: Variation in species richness per transect over time, per vegetation community. Vegetation communities were ordered per seral stage, from pioneering to late seral communities. Refer to Table 4-1 for a description of the vegetation communities.

Diversity also varied among vegetation communities and years, and similar to 2014, appeared consistently lower in 2016 than in previous years, especially for Lady's thumb-Lamb's Quarter (LL), Wool-grass-Pennsylvania Buttercup (WB), Buckbean-Slender Sedge (BS), and Cottonwood-Trifolium (CT) communities (Figure 5-7). Results from 2-way ANOVA models found that species diversity was statistically significant among years (F=9.1, p=0.0001) and between vegetation communities (F=3.6, p=0.002). Interactions were also significant (F=1.6, p=0.004); post-hoc one-way ANOVAs found significant differences among vegetation communities in 2007 (F=6.8, p=0.0001), 2012 (F=2.2, p=0.04), and 2014 (F=2, p=0.07), and among years for Clover – Oxeye daisy (CO; F=18, p=0.0001), Cottonwood – Clover (CT; F=12, p=0.0001), Kellogg's Sedge (KS; F=3.9, p=0.007), Willow – Sedge wetland (WS; F=3, p=0.07), and Common Horsetail (CH; F=3.5, p=0.01) communities. Differences in diversity for TP, BR, MA, RC, RD, MC, LH, WB, BS, DR, WD and FO communities were not tested because of lack of replicates in one or more years (see Table 4-1 for vegetation community codes).

Diversity seemed to increase slightly in the Clover-Oxeye Daisy (CO) community in 2014 and 2016 compared to 2012, slowly returning towards values recorded in 2007 and 2010.

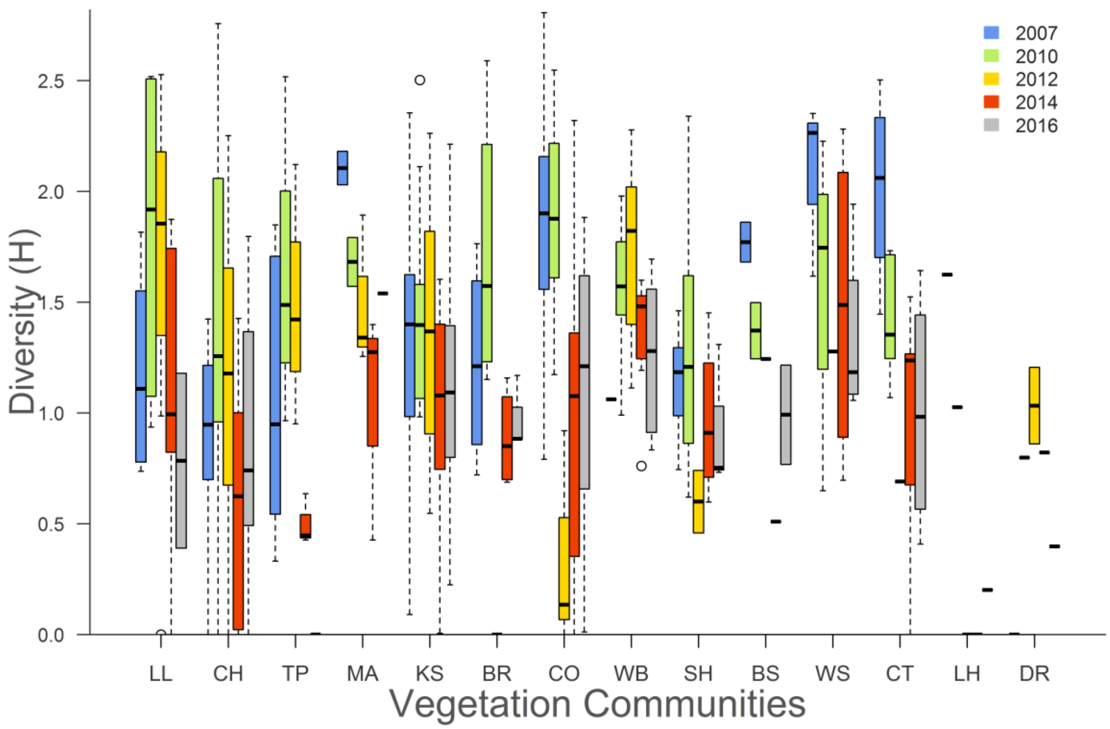

Figure 5-7: Variation in species diversity (Shannon's H) per transect over time, per vegetation community. Vegetation communities were ordered per seral stage, from pioneering to late seral communities. Refer to Table 4-1 for a description of the vegetation communities.

Assessing the variation in species richness and diversity over time confirmed several observations made in previous reports (Hawkes and Gibeau 2015). For example, species richness and diversity were both higher relative to elevation (richness and diversity: t=2.5, p=0.01 and t=2.46, p=0.01, respectively), decreased with time (richness, t=-2.2, p=0.03; diversity, t=-3.7, p=0.0003), and decreased with increasing slope (richness: t=-2, p=0.049; diversity: t=-4, p=0.0001; Figure 5-8). Species richness also varies by landscape unit, a result consistent with Figure 10-3 and Figure 10-4 (Appendix 10.2). Because elevation is correlated with water depth and the calculation of growing degree days (GDDs), the effect of water depth and GDDs were modelled separately and revealed that in addition to results consistent with the above results, species richness and/or diversity increased with increasing GDDs August (richness: t=2, p=0.04) and September (richness: t=2.6, p=0.0096), which by the nature of the calculations associated with GDDs, these results mean that reservoir water levels were reduced those months, thus exposing more vegetation bands to light and warmth. The effect of reservoir elevations on GDDs and associated effects on species richness is further supported by the fact that higher water depth in September is correlated with lower species diversity (t=-1.65, p=0.1; see Also Appendix 10.2, Figure 10-5), although there is low confidence in this result. These results emphasise the negative effects that reservoir operations, particularly, higher reservoir elevations, have on the species richness and diversity of vegetation communities that occur in the drawdown zone of Kinbasket Reservoir.

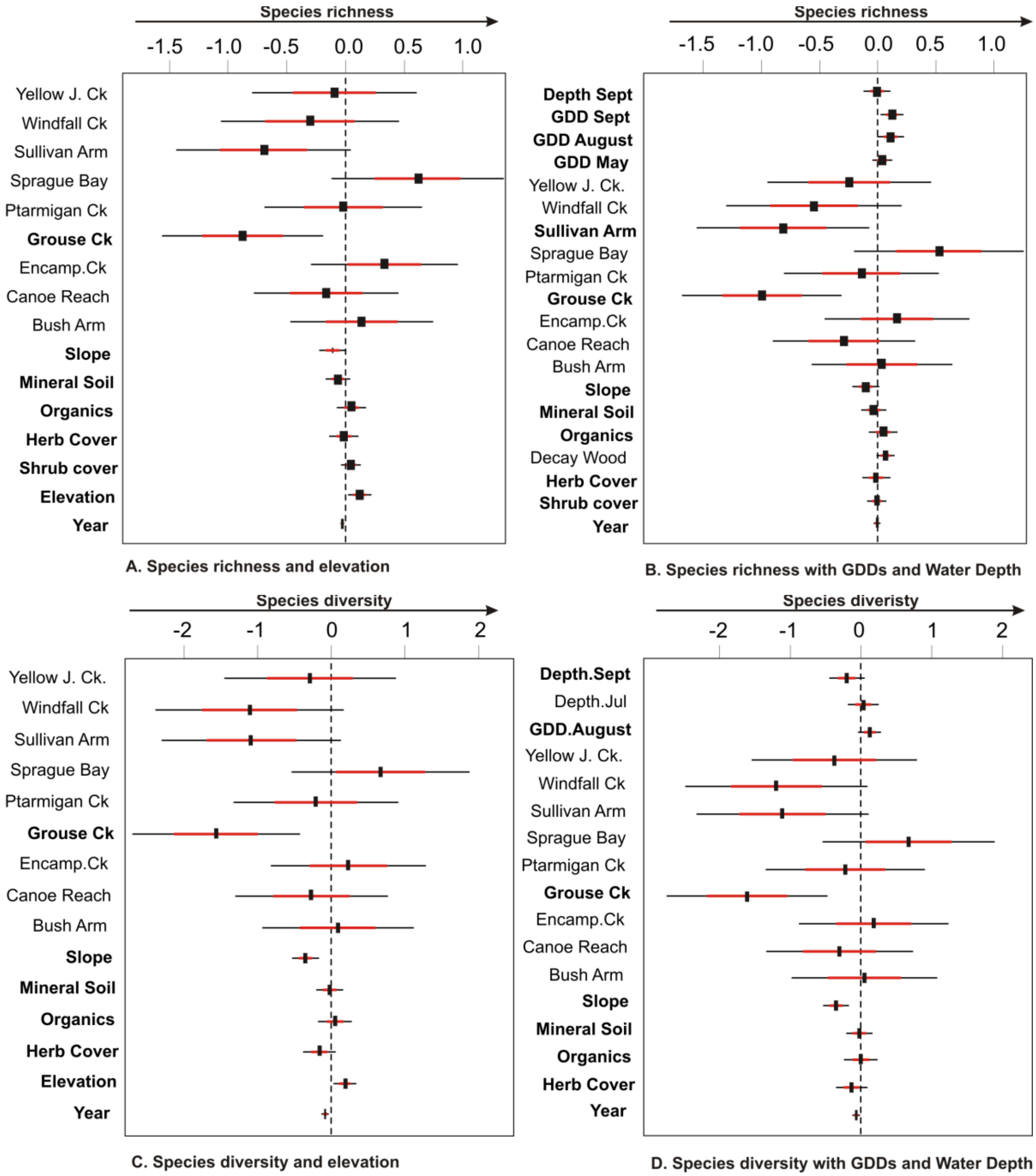

Figure 5-8: Coefficient plots showing the value of the standardized regression coefficient (black rectangles) ± 2 SE (red line) for each fixed effect included in the GLMM, along with the 95 per cent confidence interval (horizontal black lines) for fixed effects including elevation (A and C, left panels) and fixed effects with growing degree days (GDDs) and water depth (B and D, right panels). Variables with bold text were significant at α = 0.1. Values < 0 indicate species richness or species diversity was negatively correlated with the modelled explanatory variable while those > 0 indicate increasing species richness or diversity relative to the variable

5.2 Vegetation Data – Polygons

5.2.1 Spatial Extent of Vegetation Communities

Since 2007, the total spatial extent of vegetation mapped (all landscape units and vegetation communities combined) in the drawdown zone of Kinbasket Reservoir has increased by ~ 6 per cent (2016 vs. 2007; ~ 137 ha; Table 5-2, but see also Figure 10-6). The effect of year was significant (F=8.8, p<0.0001) when comparing all years to 2007, but the significance is explained by the overall reduction in the mapped extent of vegetation in the drawdown zone after 2007. Since 2007, there has been a slight increase (i.e., the ~ 137 ha). The variation within each landscape unit (LU) can be characterized as 1) stabilization following a decrease in 2007 (n=8 LUs; e.g., Beavermouth, Sullivan Arm; Windfall Creek: Figure 5-9); 2) increasing over time (n=3; e.g., Canoe Reach); 3) decreasing over time (n=1 LU; Bush Arm); or 4) variable with minor changes (n=2; e.g., Encampment Creek. The reduction in the extent of vegetation following 2007 is explained in part by the dying off of woody stemmed vegetation and increased deposition of wood debris in the drawdown zone following the first near-filling of Kinbasket Reservoir in nine years, which occurred in 2007, the first year of monitoring under CLBMON-10. Other possible explanations for the reduction in vegetation cover in 2007 include an increase in the total area covered by wood debris following the high-water event of 2007, and unmeasured (but observed) erosion and sedimentation, which will remove or cover vegetation growing in the drawdown zone.

The spatial extent of the mapped vegetation communities was variable over time, but did not differ significantly from 2007 (F=0.42; p=0.79; Table 5-3 but see also Figure 10-7). Following 10 years of study, vegetation communities can be characterised as 1) stable (n=3; e.g., MA); 2) increasing (n=3; e.g., TP); 3) increasing in extent and stabilizing (n=4; e.g., BR); 4) variable (no discernable pattern; n=2; e.g., CO); 5) decreasing (n=3; e.g., CH); or 6) decreasing and then stabilizing (n=6; e.g., SH; Table 5-3). The variation in type and direction of change observed at the vegetation community level is indicative of the complexity and behaviour of processes influencing the drawdown zone of Kinbasket Reservoir. For example, increasing reservoir elevations and wood debris inputs can interact to increase the effects of wood debris scour on vegetation, but because of prevailing winds (south to north), the effects of wood debris scour will be applied differentially at each landscape unit. Depending on the size, shape, exposure, and elevation of the landscape units, different vegetation communities may be affected differently. The individual effects of reservoir and wood debris scour on each vegetation community at each landscape unit are not directly measurable (due to the sampling intensity associated with CLMBON-10) and as such, neither are the interactions between reservoir elevations and wood debris.

Table 5-2: The spatial extent of vegetation (hectares) mapped for each landscape unit and year using aerial imagery and field data. Landscape units are ordered from South to North in Kinbasket Reservoir. '=' indicates no or very minor (< 10 per cent) change, '↓' indicates a decline in spatial extent in 2016 compared to 2007, and '↑' indicates an increase in spatial extent in 2016 as compared to 2007. Combinations of symbols provide an indication of changes in extent of cover within each community over time. 16v7 = 2016 vs. 2007, etc.

	Year					Change in area (ha)				Per cent change				
Landscape Unit	**07**	**10**	**12**	**14**	**16**	**16v7**	**16v10**	**16v12**	**16v14**	**16v7**	**16v10**	**16v12**	**16v14**	**Direction**
Beavermouth	31.1	26.3	26.3	26.1	25.6	-5.6	-0.7	-0.7	-0.5	-18%	-3%	-3%	-2%	↓; =
Bush Arm	1064.2	1021.9	1021.2	912.1	907.2	-157.0	-114.7	-114.1	-5.0	-15%	-11%	-11%	-1%	↓
Succour Creek	--	121.4	121.5	261.0	261.0	261.0	139.7	139.6	0.0	100%	115%	115%	0%	↑; =
Sullivan Arm	7.8	1.9	1.8	1.8	1.8	-6.0	-0.1	-0.1	0.0	-77%	-5%	-6%	0%	↓; =
Sprague Bay	--	33.4	33.4	35.0	33.7	33.7	0.3	0.3	-1.3	100%	1%	1%	-4%	↑;↓
Encampment Creek	71.4	68.4	68.5	70.7	69.4	-2.0	1.0	0.9	-1.3	-3%	1%	1%	-2%	↑;↓
Howard Creek	15.2	11.6	11.6	12.1	11.9	-3.4	0.2	0.2	-0.2	-22%	2%	2%	-2%	↓; =
Hugh Alan Bay	35.8	37.3	37.0	40.5	40.5	4.6	3.1	3.5	0.0	13%	8%	9%	0%	↑
Windfall Creek	44.1	13.9	14.6	16.6	16.1	-28.1	2.1	1.4	-0.5	-64%	15%	10%	-3%	↓; =
Grouse Creek	43.7	12.8	12.9	14.0	13.4	-30.3	0.7	0.5	-0.6	-69%	5%	4%	-4%	↓; =
Mount Blackman	14.5	4.2	4.2	5.2	5.2	-9.3	1.1	1.0	0.0	-64%	26%	24%	0%	↓; =
Ptarmigan Creek	20.1	15.8	15.9	15.5	15.5	-4.6	-0.3	-0.4	0.0	-23%	-2%	-3%	0%	↓; =
Yellowjacket Creek	46.2	31.8	31.8	32.0	31.5	-14.7	-0.3	-0.3	-0.4	-32%	-1%	-1%	-1%	↓; =
Canoe Reach	703.0	770.6	771.8	800.8	801.3	98.3	30.7	29.5	0.5	14%	4%	4%	0%	↑
All Landscape Units	2097.3	2171.3	2172.6	2243.3	2234.0	136.8	62.8	61.4	-9.3	6%	3%	3%	0%	↑

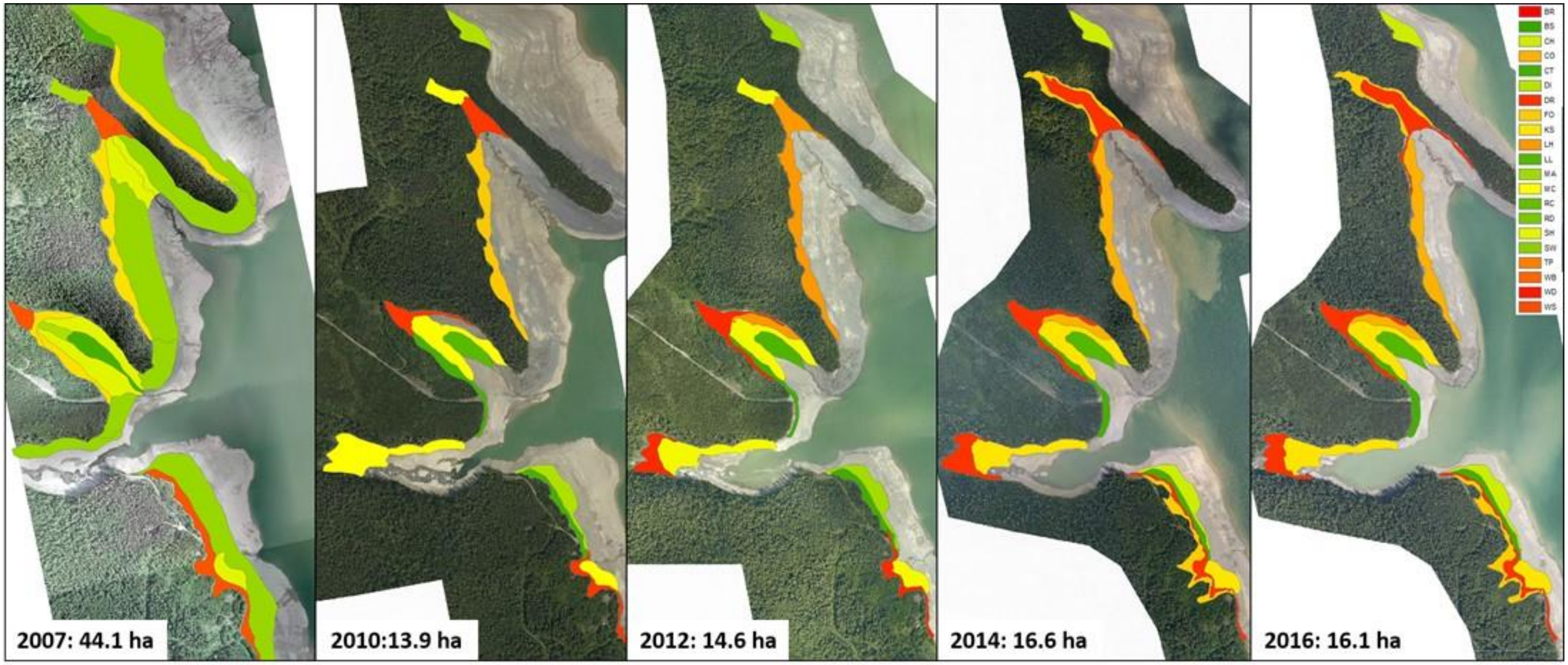

Figure 5-9: Example of changes in the spatial extent of mapped vegetation at Windfall Creek, 2007 to 2016. The reduction following 2007 was related to refined mapping methods and the acquisition of field data (see Hawkes et al 2010). The variation in spatial extent from 2010 to 2016 was minimal. Vegetation codes are expanded in Table 4-1

Table 5-3: Spatial extent of vegetation (hectares) sampled from aerial photography in each vegetation community since 2007. Vegetation communities are ordered from early pioneering to late seral stages in Kinbasket Reservoir. '=' indicates no or very minor (< 10 per cent) change, '↓' indicates a decline in spatial extent in 2016 compared to 2007, and '↑' indicates an increase in spatial extent in 2016 as compared to 2007. Combinations of symbols provide an indication of changes in extent of cover within each community over time. 16v7 = 2016 vs. 2007, etc. See Table 4-1 for VCC definitions.

	Year					Change in area (ha)				Per cent change				
VCC	**2007**	**2010**	**2012**	**2014**	**2016**	**16v7**	**16v10**	**16v12**	**16v14**	**16v7**	**16v10**	**16v12**	**16v14**	**Direction**
LL	569.88	719.08	713.08	707.81	718.18	148.3	-0.9	5.1	10.37	26%	0%	1%	1%	↑; =
CH	339.71	280.47	282.17	281.18	268.45	-71.26	-12.02	-13.72	-12.73	-21%	-4%	-5%	-5%	↓
TP	88.99	266.87	265.05	290.18	290.6	201.61	23.73	25.55	0.42	227%	9%	10%	0%	↑
MA	106.13	110.2	110.44	110.41	110.21	4.08	0.01	-0.23	-0.2	4%	0%	0%	0%	=
KS	233.64	210.17	215.61	215.05	206.92	-26.72	-3.25	-8.69	-8.13	-11%	-2%	-4%	-4%	↓
BR	16.77	41.5	40.68	40.92	39.46	22.69	-2.04	-1.22	-1.46	135%	-5%	-3%	-4%	↑; =
RC	9.37	31.47	27.99	25.32	27.76	18.39	-3.71	-0.23	2.44	196%	-12%	-1%	10%	↑; =
RD	--	0.59	0.59	0.52	0.52	0.52	-0.07	-0.07	0	--	-12%	-12%	0%	↓; =
CO	161.43	135.67	125.24	119.71	130.18	-31.25	-5.49	4.94	10.47	-19%	-4%	4%	9%	↓;↑
WB	4.51	128.85	129.74	143.88	142.95	138.44	14.1	13.21	-0.93	3070%	11%	10%	-1%	↑; =
SH	146.91	52.41	55.04	43.26	44.62	-102.29	-7.79	-10.42	1.36	-70%	-15%	-19%	3%	↓; =
BS	9.3	12.02	10.69	10.93	11.18	1.88	-0.84	0.49	0.25	20%	-7%	5%	2%	=
WS	36.78	34.47	32.37	34.7	40.76	3.98	6.29	8.39	6.06	11%	18%	26%	17%	=
CT	46.97	20.95	19.57	15.99	14.89	-32.08	-6.06	-4.68	-1.1	-68%	-29%	-24%	-7%	↓; =
LH	4.36	0.52	0.52	0.52	0.52	-3.84	0	0	0	-88%	0%	0%	0%	↓; =
MC	18.66	0.22	0.19	0.1	0.1	-18.56	-0.12	-0.09	0	-99%	-55%	-47%	0%	↓; =
DR	27.96	36.83	47.86	56.69	45.92	17.96	9.09	-1.94	-10.77	64%	25%	-4%	-19%	↑;↓
FO	21.56	18.99	16.57	45.28	43.18	21.62	24.19	26.61	-2.1	100%	127%	161%	-5%	↑
WD	254.32	69.99	79.21	56.33	56.33	-197.99	-13.66	-22.88	0	-78%	-20%	-29%	0%	↓; =
DI	--	--	--	21.61	25.19	25.19	25.19	25.19	3.58	--	--	--	14%	↑
SW	--	--	--	22.92	16.11	16.11	16.11	16.11	-6.81	--	--	--	-42%	↓
Total	**2097.25**	**2171.27**	**2172.6**	**2243.32**	**2234.04**	**136.79**	**62.77**	**61.44**	**-9.28**	**6%**	**3%**	**3%**	**0%**	

Variation in spatial extent in response to factors such as vegetation community, year, growing degree days (GDD), and water depth is illustrated in Figure 5-10. Spatial extent varied significantly between communities with nine communities (WS, WB, TP, SH, RC, MA, LL, KS, CH; Table 10-1) showing a significant increase in spatial extent compared to the CO community, whereas four communities (MC, FO, DR, and CT) showed a significant decrease in spatial extent compared to the CO community (Figure 5-10; Table 10-1). While taking all factors into account, the spatial extent of vegetation communities in general was positively correlated with year, although the confidence in this result is weak (see Figure 5-8).

The spatial extent of communities also varied with the amount of growing degree days (GDD) and water depth (Figure 5-10). Spatial extent decreased with GDD in June
(t=-2.9;p=0.003) and July (t=-3;p=0.003). Notably, spatial extent decreased with increasing water depth in July (t=-3.1;p=0.002), but increased with increasing water depth in September (t=-2.2;p=0.03).

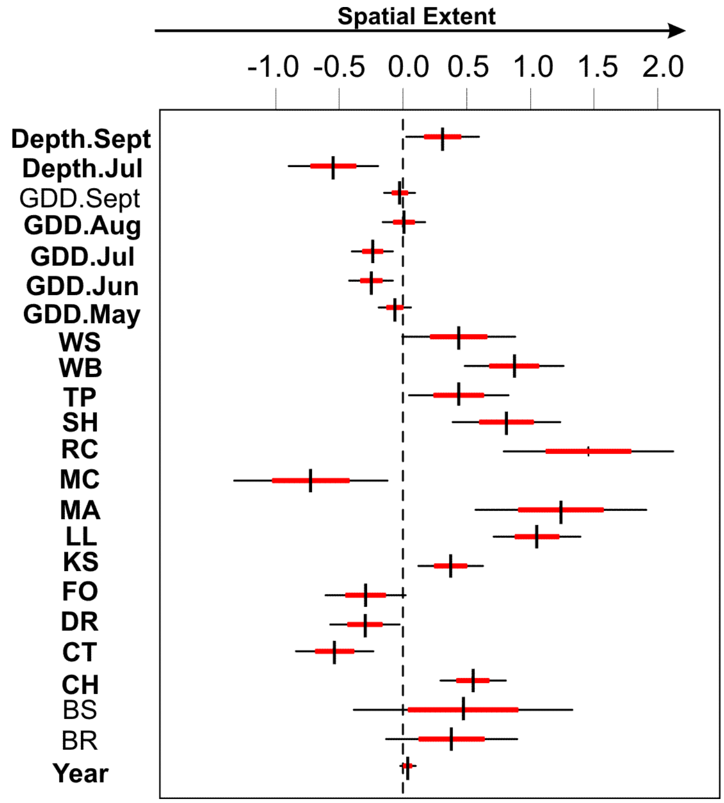

Figure 5-10: Coefficient plots showing the value of the standardized regression coefficient (black rectangles) ± 2 SE (red line) for each fixed effect included in the GLMM, along with the 95 per cent confidence interval (horizontal black lines) for fixed effects, including growing degree days (GDD) and water depth. Variables with bold text were significant at α = 0.1. Values < 0 indicate spatial extent was negatively correlated with the modelled explanatory variable while those > 0 indicate increasing spatial extent relative to the variable. Vegetation community codes are defined in Table 4-1.

The variation in size among polygons in each vegetation community is illustrated by Figure 5-11. Large polygons were mapped mostly for early pioneering vegetation communities (i.e., LL, TP, and KS), with some polygons reaching over 250 ha. However, the large majority of polygons were much smaller than 50 ha (average=3.7 ha, SD=4.3 ha, median=1.4 ha). Notably, the WD community had larger polygons than other late-seral communities.

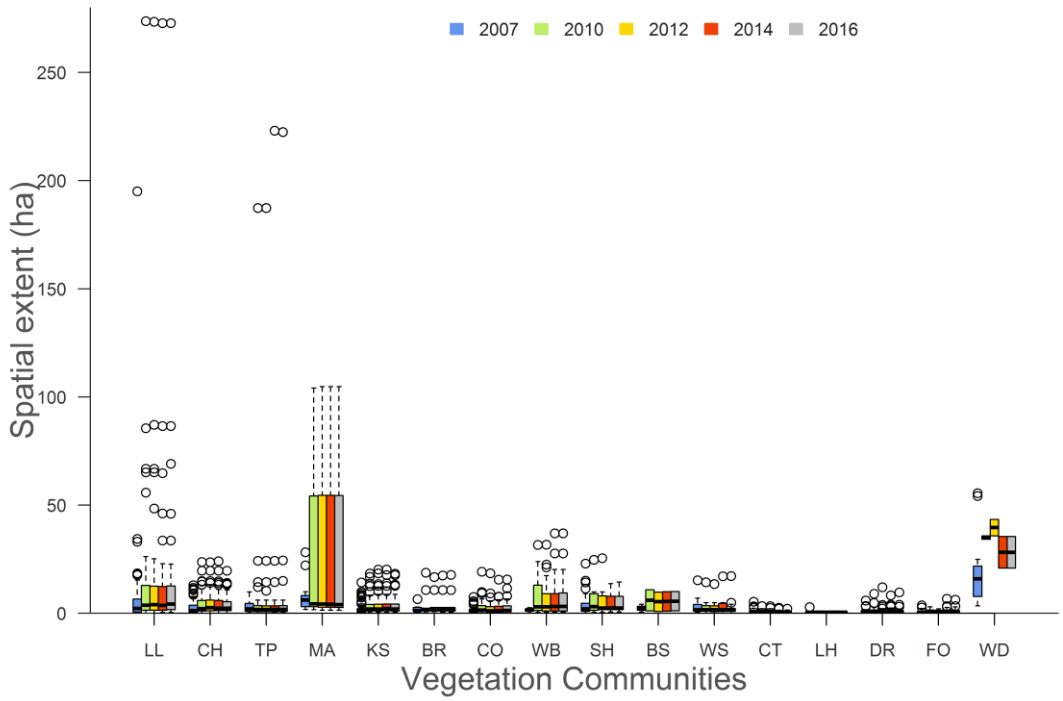

Figure 5-11: Variation in spatial extent (ha) over time across the different vegetation communities in Kinbasket Reservoir. Vegetation communities are ordered from early pioneering to late seral stages.

The distribution of vegetation communities by landscape unit and year is shown in Figure 5-12. 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 (CNR) and Bush Arm (BSA) 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 2016 was the pioneering LL community in Bush Arm and Canoe Reach; as was the case in 2007, 2012 and 2014 (Figure 5-12). The spatial extent of the LL community has been relatively stable over time. Over all sampling years in general, 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 5-3; Figure 5-12). Most landscape units had much smaller spatial extents of vegetation communities than Canoe Reach and Bush Arm. Similar to previous years, 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).

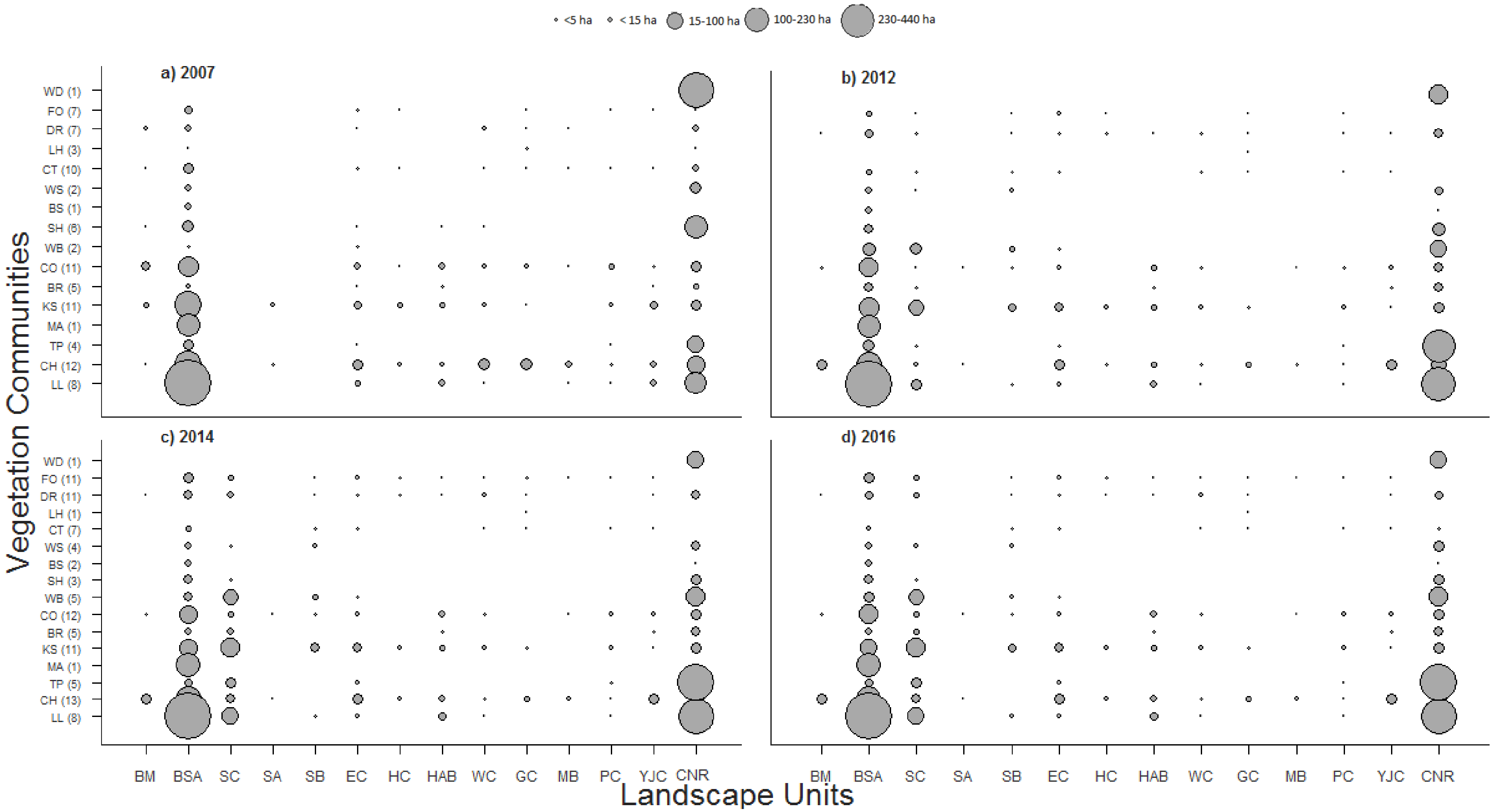

Figure 5-12: The relative distribution of each vegetation community by year and landscape unit. Vegetation community codes are defined in Table 4-1. The size of the points is proportional to the communities' spatial extent in the landscape unit over time. The number in brackets after the vegetation community codes refers to the total number of landscape units in which that community occurs. Landscape units are ordered from south to north: BM = Beavermouth; BSA = Bush Arm; SC = Succour Creek; SA = Sullivan Arm; SB = Sprague Bay; EC = Encampment Creek; HC = Howard Creek; HAB = Hugh Alan Bay; WC = Windfall Creek; GC = Grouse Creek; MB = Mount Blackman; PC = Ptarmigan Creek; YJC = Yellow Jacket Creek; CNR = Canoe Reach.

The spatial extent of vegetation was maximal at an elevation of 743 m in Kinbasket Reservoir in 2016 (Figure 5-13). 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.

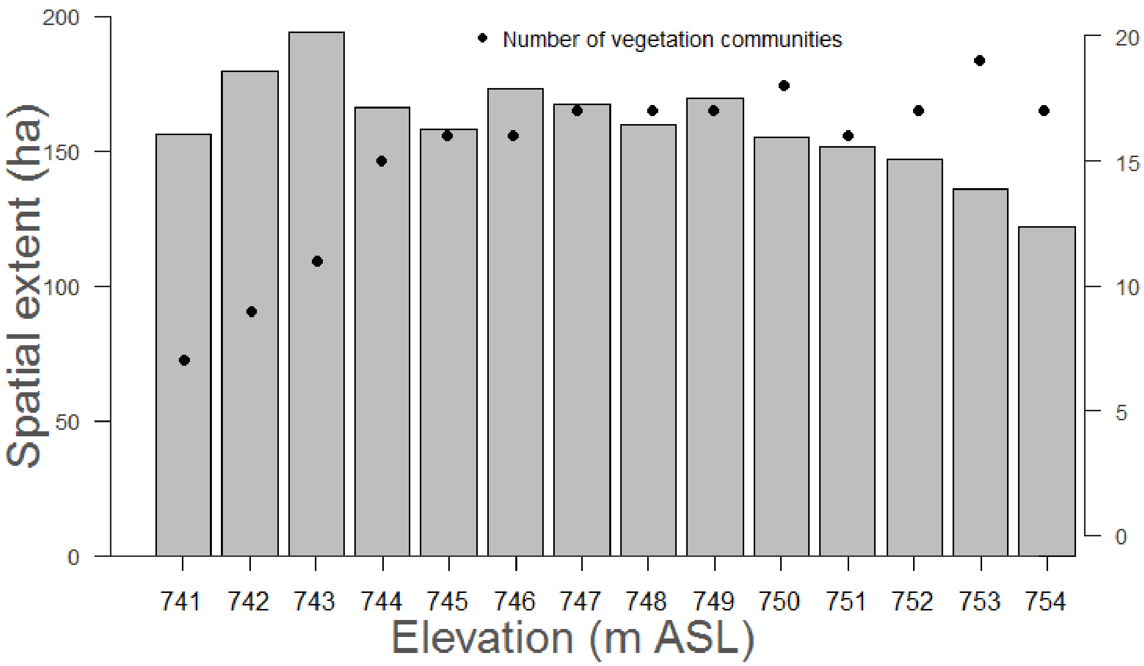

Figure 5-13: Total spatial extent (left axis) and number of vegetation communities (right axis) per elevation band in 2016.

5.2.2 Vegetation Communities and Landscape Unit

The number of vegetation communities mapped per landscape unit and year has remained relatively stable over time (Figure 5-14). The only reduction is in the number of vegetation communities and that occurred after 2007, but since then the number of vegetation communities has stayed the same (e.g., Sullivan Arm; SA and Howard Creek, HC), increased in 2014 with no change in 2016 (e.g., Bush Arm, BSA and Beavermouth (BM), or increased over time (Yellowjacket Creek, YJC and Canoe Reach, CNR). One community (Ptarmigan Creek, PC) has remained stable over time with the addition of one community in 2012 (the DR community), which was no longer present in 2014 or 2016.

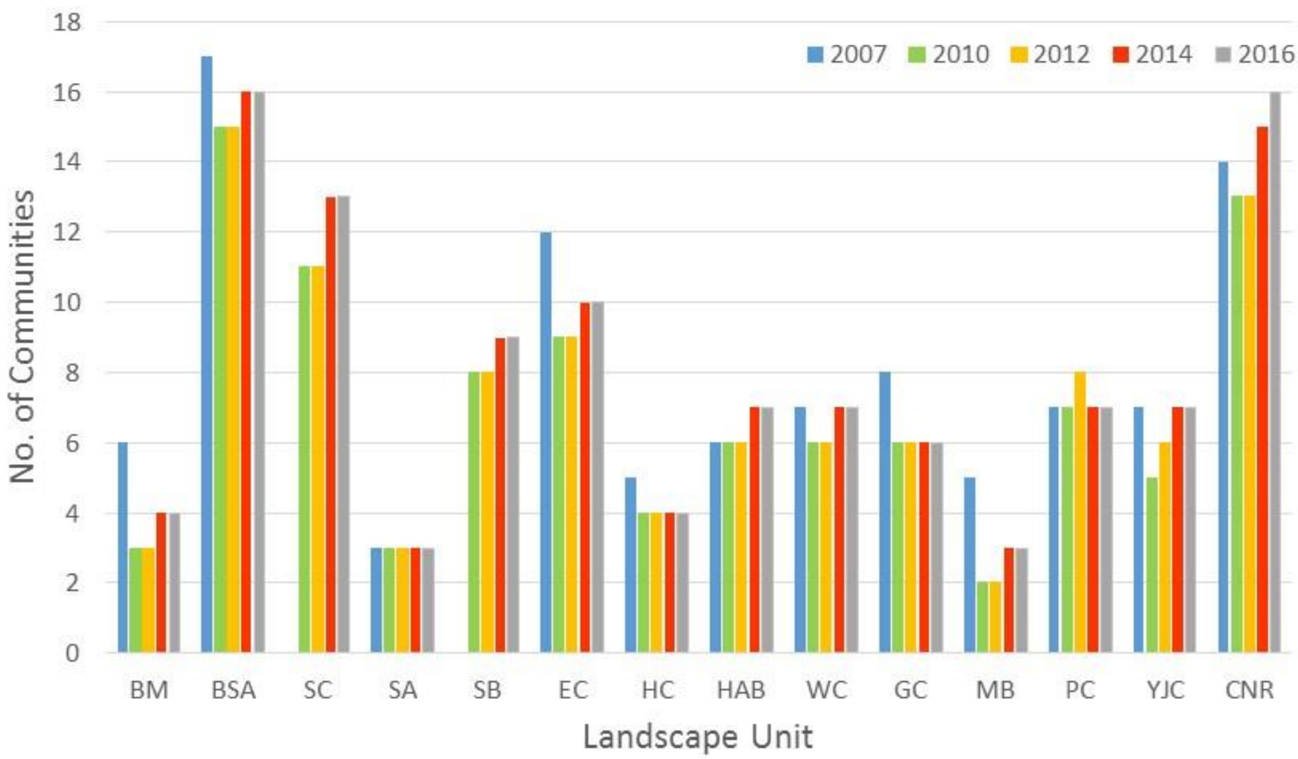

Figure 5-14: Number of vegetation communities mapped per landscape unit in 2007, 2010, 2012, 2014, and 2016. Landscape units are ordered south to north: BM = Beavermouth; BSA = Bush Arm; SC = Succour Creek; SA = Sullivan Arm; SB = Sprague Bay; EC = Encampment Creek; HC = Howard Creek; HAB = Hugh Alan Bay; WC = Windfall Creek; GC = Grouse Creek; MB = Mount Blackman; PC = Ptarmigan Creek; YJC = Yellow Jacket Creek; CNR = Canoe Reach.

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 5-15). 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. For example, erosion events have been observed at Packsaddle Creek (Figure 5-16) and Windfall Creek and sediment deposition is evident in regions of Bush Arm and at Hugh Alan Bay.

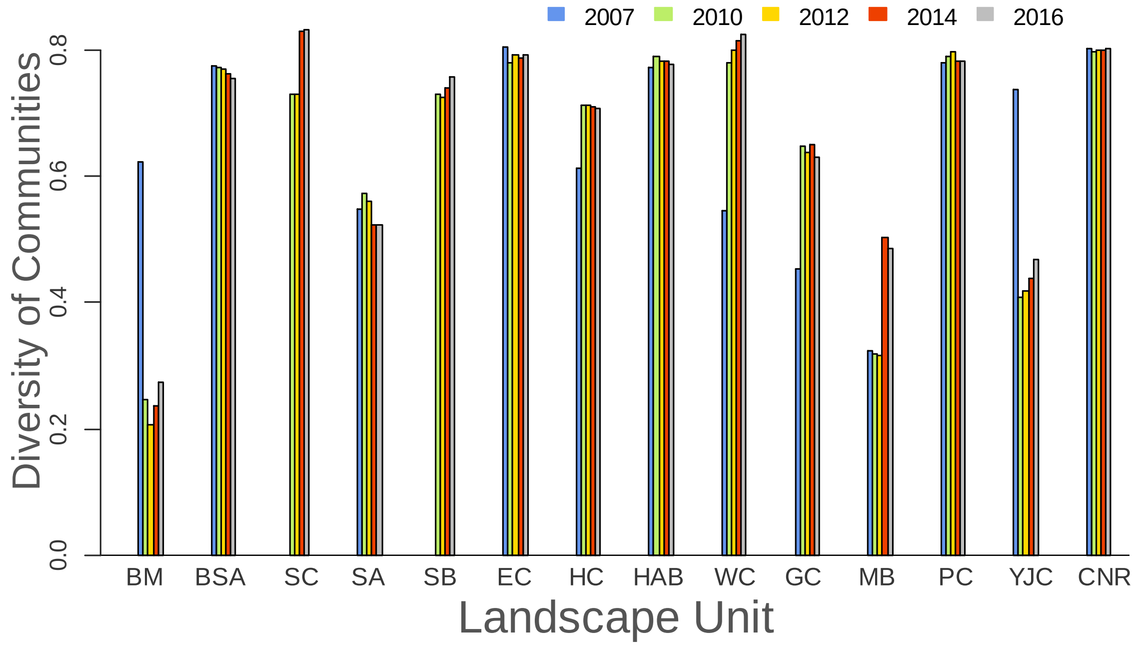

Figure 5-15: Diversity (Simpson's index) of vegetation communities mapped per landscape unit in 2007, 2010, 2012, 2014, and 2016. Landscape units are ordered south to north: BM = Beavermouth; BSA = Bush Arm; SC = Succour Creek; SA = Sullivan Arm; SB = Sprague Bay; EC = Encampment Creek; HC = Howard Creek; HAB = Hugh Alan Bay; WC = Windfall Creek; GC = Grouse Creek; MB = Mount Blackman; PC = Ptarmigan Creek; YJC = Yellow Jacket Creek; CNR = Canoe Reach

Figure 5-16: Evidence of erosion of upland habitat near Packsaddle Creek at the normal full pool elevation (~ 754 m ASL) of Kinbasket Reservoir

Table 5-4 details the changes in vegetation communities mapped for each landscape units between 2007 and 2016. In general, the same communities were sampled in 2010, 2012, 2014, and 2016, 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, 2014, and 2016. See Figure 5-12 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 5-4: 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 sampled in given landscape units. The grand total corresponds to the total number of vegetation communities that were mapped over the five years. Landscape units are ordered from south to north, and vegetation communities ordered from pioneering to late seral stages. Vegetation community codes are defined in Table 4-1. Disturbed (DI) and Shrub Willow (SW) are not used in analyses.

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	DI	SW	
Beavermouth	2007																						6
	2010																						3
	2012																						3
	2014																						3
	2016																						4
	Total		5			1				5		1			1			5			2		7
Bush Arm	2007																						17
	2010																						15
	2012																						15
	2014																						16
	2016																						16
	Total	5	5	5	5	5	5	5		5	5	5	5	5	5	1	1	5	5			2	18
Succour Creek	2007																						--
	2010																						11
	2012																						11
	2014																						13
	2016																						13
	Total	4	4	4		4	4			4	4	2		4	2			4	4		2	2	14
Sullivan Arm	2007																						4
	2010																						3
	2012																						3
	2014																						3
	2016																						3
	Total	1	5			1				4							5						5
Sprague Bay	2007																						--
	2010																						8
	2012																						8
	2014																						9
	2016																						9
	Total	4				4				4	4			4	4			4	4			2	9
Encampment Creek	2007																						12
	2010																						9
	2012																						9
	2014																						10
	2016																						10
	Total	5	5	5		5	1			5	5	1			5		1	5	5			2	13
Howard Creek	2007																						5
	2010																						4
	2012																						4
	2014																						4
	2016																						4
	Total		5			5				1					1			4	5				6

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	DI	SW	
Hugh Alan Bay	2007																						6
	2010																						6
	2012																						6
	2014																						7
	2016																						7
	Total	5	5			5	5			5		1						4	2				8
Windfall Creek	2007																						7
	2010																						6
	2012																						6
	2014																						7
	2016																						7
	Total	5	5			5				5		1			5			5	2				8
Grouse Creek	2007																						8
	2010																						6
	2012																						6
	2014																						6
	2016																						6
	Total		5			5				1					5	5	1	5	5				8
Mount Blackman	2007																						5
	2010																						2
	2012																						2
	2014																						3
	2016																						3
	Total	1	5							5					1			1	2				6
Ptarmigan Creek	2007																						7
	2010																						7
	2012																						8
	2014																						7
	2016																						7
	Total	5	5	5		5				5					5			1	5				8
Yellowjacket Creek	2007																						7
	2010																						5
	2012																						6
	2014																						7
	2016																						7
	Total	1	5			5	5			5					5			3	3				8
Canoe Reach	2007																						14
	2010																						13
	2012																						13
	2014																						15
	2016																						16
	Total	5	5	5		5	5		4	5	4	5	4	5	2	1	1	5	1	5	2	2	19

Between 2007 and 2016, a total of eight vegetation communities (MA, RC, WB, SH, LH, DR, MC, MD) had > 50 percent of their polygons change their vegetation community from that originally assigned in 2007 (Figure 5-17). This was maximal for the RC and WB communities where they had nearly a four- to six-fold increase in the number of polygons assigned to their communities in 2016 compared to 2007 (Figure 5-17).

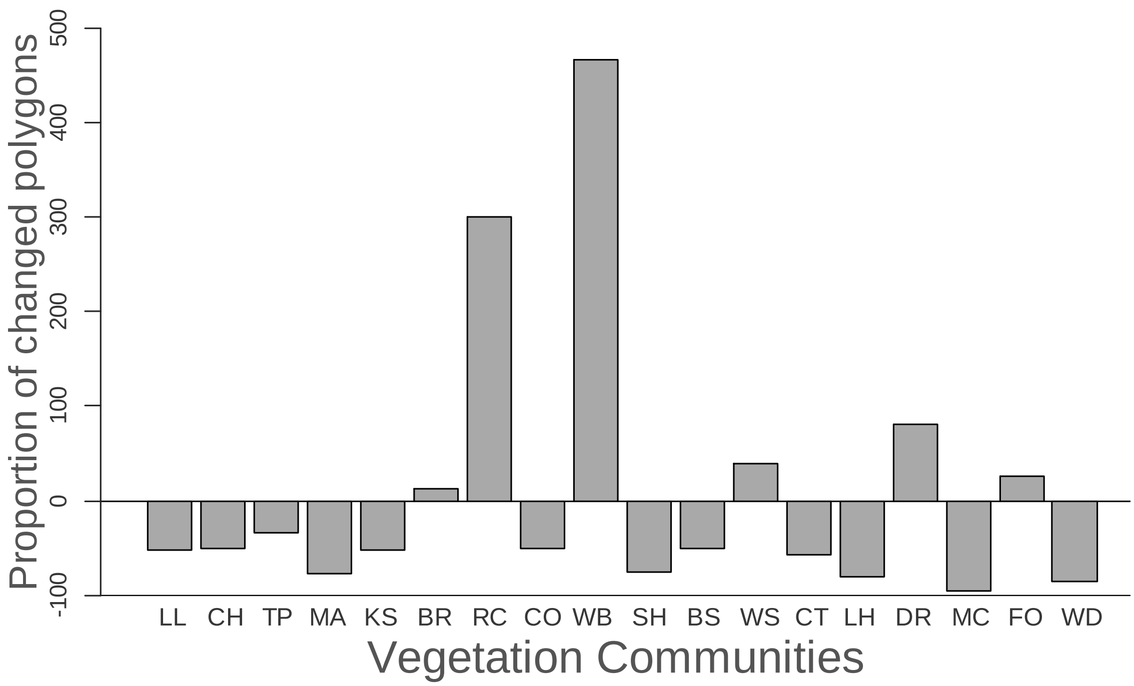

Figure 5-17: Proportion of polygons that changed vegetation community between 2007 and 2016 for each community type that was mapped in 2007. Negative proportions indicate a decline in the number of polygons that were mapped to that vegetation community in 2016 and compared to 2007, while positive proportions mean an increase in the number of polygons associated with a given vegetation community in 2016. Vegetation communities are ordered from early pioneering to late seral stages. Vegetation community codes are defined in Table 4-1.

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 2016; WS communities were also very stable with all six polygons mapped in that community in 2007 remaining the same in 2016 (Table 5-5).

The vegetation communities with the most polygons mapped between 2007 and 2014 (KS, CO, and CH) were also the ones that were the most unstable (Table 5-5). For example, many of the polygons that were mapped in CO and KS communities in 2007 changed to CH communities in 2016. Consequently, 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 2016 compared to 2007.

Table 5-5: Frequency of vegetation communities of the 226 polygons tested between 2007 and 2016, along with the individual values of the kappa statistics and associated p-value. The overall kappa statistic was k=0.509 (p=0, 95% CI=0.435, 0.58). Vegetation community codes are defined in Table 4-1. Disturbed (DI) and Shrub Willow (SW) are not used in analyses.

Vegetation Community	Frequency in 2007	Frequency in 2016	Kappa	z	p.value
LL	80	39	0.738	11.087	0
CH	135	66	0.583	8.762	0
TP	29	19	0.404	6.081	0
MA	13	3	0.662	9.955	0
KS	120	58	0.462	6.948	0
BR	8	9	0.386	5.809	0
RC	1	4	0.496	7.45	0
RD	0	1	-0.002	-0.033	0.973
CO	110	54	0.377	5.665	0
WB	3	17	0.129	1.936	0.053
SH	37	9	0.372	5.596	0
BS	4	2	0.664	9.989	0
WS	10	14	0.741	11.137	0
CT	51	22	0.239	3.586	0
LH	5	1	0.496	7.45	0
MC	24	1	0.206	3.103	0.002
DR	21	38	0.725	10.904	0
FO	30	38	0.863	12.967	0
WD	13	2	0.798	11.993	0
DI	0	5	--	--	--
SW	0	16	--	--	--

Overall, most differences in vegetation characteristics at the landscape level seemed to occur after 2007, either in terms of decline in spatial extent (Table 5-3; Figure 5-12), identity of communities (Table 5-4), or decline in number and diversity of communities (Figure 5-13, Figure 5-14, Figure 5-15, and Figure 5-17; Table 5-5), 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.

6.0 DISCUSSION

6.1 Summary

The 2016 field season represented the sixth 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 experiencing; however, the analyses performed in 2016 revealed some interesting patterns in species richness, diversity, and spatial extent:

Species Richness and Diversity

- Species richness and diversity increase with elevation;
- Species richness and diversity increase with increasing organic matter;
- Species richness and diversity are positively correlated with an increase in GDDs in August;
- Species richness increases with increasing number of GDDs in May and September;
- Species richness varies by landscape unit (no discernable patterns);
- Species richness and diversity have decreased with time (years);
- Species richness and diversity decrease as slope increases; and
- Species richness and diversity decreases when reservoir elevations are high in September (deep water).

Spatial Extent of Vegetation

- The total spatial extent of vegetation increased (slightly) with time (see Figure 10-6);
- Spatial extent of vegetation increased with high water in September;
- The spatial extend of vegetation varied relative to vegetation community;
- Spatial extent of vegetation was lower when GDDs were lower in May, June, July, and August; and
- Spatial extent of vegetation decreased with increasing water depth in July.

While the strength of some of these results is weak (the confidence intervals overlap slightly with 0; see Figure 5-8) they provide an indication of the variables that are responsible for the changes observed in vegetation community composition (i.e., richness) and total area over time. They also emphasize some of the variables that may be important when considering how to ensure vegetation communities persist in the drawdown zone. For example, areas with higher organic content tend to have higher species richness and when reservoir elevations are lower (i.e., water depth is lower), the number of GDDs increases and species richness and spatial extent tend to increase. These results suggest that modifications to reservoir operations would contribute to increases in the spatial extent and richness of vegetation growing in the drawdown zone of Kinbasket Reservoir.

Since 2007, we have characterized and mapped 19 vegetation communities in the drawdown zone (Table 4-1). We have also recorded 291 plant species (274 if 2008 data are excluded). Species constancy (the proportion of all species observed in 2016 that were also recorded in at least one other year) was rather low at 21 per cent. 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 observer oversight. Regardless, 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) applied to vegetation and environmental data 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 2016 data, they do suggest that the multiple and varied effects of reservoir operations and associated covariates has measureable effects on the vegetation communities that exist in the drawdown zone. 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 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.

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 (Figure 10-5). The decline has been more apparent since 2012 following two successive years of reservoir surcharge and periods of increased duration of inundation at these elevations. Declines in species richness and diversity were also observed in some lower elevations (748 and 749 m ASL) and overall, the trend appears to be declining richness and diversity over time (Figure 5-8). Given these current data, it appears that community dynamics are negatively influenced by reservoir operations and this trend is more apparent at elevations > 748 m ASL.

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 observed 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 Packsaddle Creek (Figure 5-16), 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 (from the southeast), i.e., up the reach (Figure 6-1). The prevailing wind in Bush arm is from west to east (Hawkes 2015) so wind in Bush Arm 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) and Marsh cudweed-annual hairgrass (MA) communities.

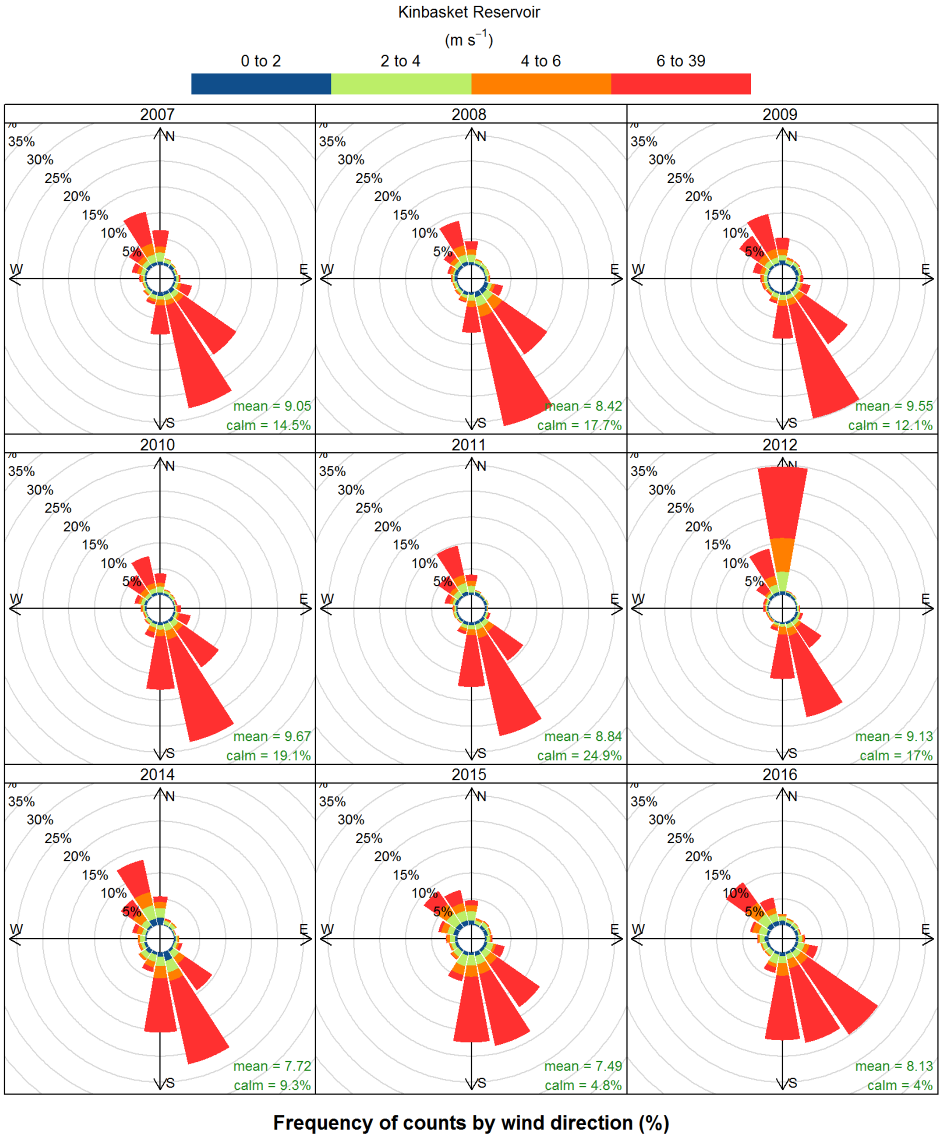

Figure 6-1: Prevailing wind patterns between April and September, 2007 to 2016 (excluding 2013 for which there are no data) in Kinbasket Reservoir

At the mapping level, and as noted above, the spatial extent of vegetation was variable at the landscape and vegetation community levels with a slight increase overall over time (Figure 10-6 and Figure 10-7). With the acquisition of LiDAR in 2014, there is some uncertainty with respect to the total extent of vegetation in the drawdown zone between 741 and 754.38 m ASL. A cursory review of the LiDAR data with existing aerial imagery suggests that the spatial extent of at least 10 vegetation communities would change and the extent of mapping at some landscape units (e.g., Canoe Reach) would be expanded. With the changes in vegetation mapping relative to the LiDAR would be the need to recalculate the effects of reservoir operations on variables such as GDDs and water depth.

6.3.1 Vegetation Communities, Inundation, and Climatic Variables

6.3.1.1 Reservoir Operations

Since 2007 the water levels in Kinbasket Reservoir were at or near the average for the 20 year period before 2007, but well above the average from mid-June to the end of fall, which corresponds to the majority of the growing season (Figure 6-2). In 2016, reservoir elevations were much higher than the 20 year average and all other year of sampling associated with CLBMON-10 between March and the middle of June, and higher than the 20 year average through December. 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.

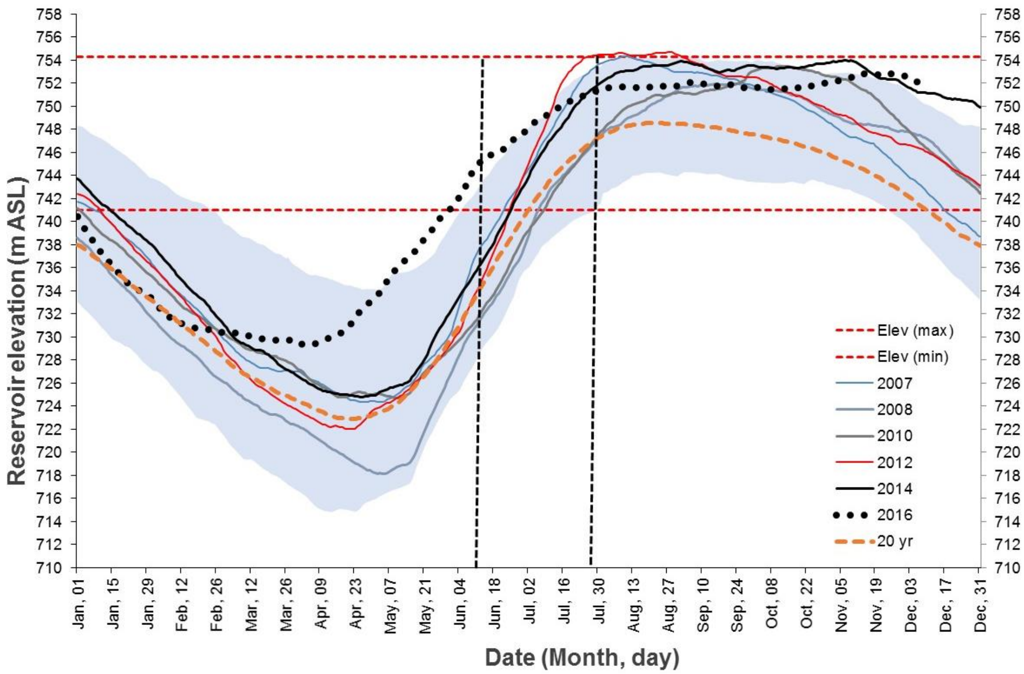

Figure 6-2: Variation in water level (m ASL) from 2007 to December 16, 2016 for Kinbasket Reservoir. The 20 year average is shown (1987 to 2006) and the horizontal dashed red lines indicate the elevation range of interest associated with CLMBON-10; the dashed black vertical lines represent the first and last date of sampling over all years

Those trends are reflected in the proportion of time that the water levels exceeded a given elevation band during the growing season (Table 6-1); 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 and although the reservoir did not reach full pool in 2016, elevations > 748 m ASL were under water for longer than average.

The vegetation communities defined and classified in 2007, particularly those in the higher elevation bands (i.e., > 748 m ASL), had developed over a number of years when the reservoir did not reach full pool (Figure 4-2). 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 in previous reports (Hawkes and Gibeau 2015) suggested that the richness and diversity of certain high elevation communities like the Willow-Sedge (WS) community had decreased over time. Results from 2016 suggest that higher elevation communities like the WS and Buckbean-Slender Sedge (BS) communities are associated with increases in species richness (Figure 5-6), suggesting a rebound from the effects of reservoir inundation and surcharge in 2012 and 2013. This could be an indication that certain vegetation communities require a period of up to three growing seasons to recover from reservoir operations that create long periods of deep water during the growing season. The ability of these communities to rebound after only a few growing seasons may be an indication that these communities are more resilient to varying reservoir operations

The variation in reservoir operations in terms of duration of inundation, particularly at higher elevations (Table 6-1) is likely one the main factors influencing species richness and diversity. A reduction in inundation rates or duration is also considered one of the main contributors to vegetation establishment and development, and ultimately to increases in the total extent of vegetation with a reduction in inundation correlated with increased spatial extent (particularly in July; Figure 5-10).

Table 6-1: Proportion of time that Kinbasket Reservoir exceeded a given elevation band (m ASL) in the drawdown zone for the months of April – September, 2005 – 2016. For example, in 2014, water levels exceeded the elevation of 741 m for 98 out of 183 days (98/183 = 0.54). Shaded cells indicate that the reservoir did not exceed a given elevation band

m ASL	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
741-742	0.55	0.59	0.55	0.48	0.53	0.46	0.54	0.54	0.52	0.54	0.70	0.67
742-743	0.54	0.58	0.54	0.46	0.51	0.45	0.52	0.53	0.51	0.52	0.67	0.65
743-744	0.51	0.56	0.52	0.44	0.48	0.43	0.51	0.52	0.50	0.51	0.65	0.63
744-745	0.50	0.54	0.50	0.42	0.46	0.42	0.49	0.50	0.49	0.49	0.64	0.62
745-746	0.48	0.52	0.49	0.39	0.43	0.39	0.48	0.50	0.49	0.48	0.62	0.61
746-747	0.46	0.51	0.48	0.37	0.40	0.37	0.46	0.49	0.47	0.46	0.61	0.56
747-748	0.41	0.49	0.46	0.34	0.37	0.35	0.45	0.47	0.46	0.45	0.54	0.53
748-749	0.35	0.48	0.44	0.32	0.34	0.33	0.43	0.46	0.44	0.43	0.38	0.50
749-750	0.28	0.45	0.43	0.27	0.31	0.31	0.42	0.45	0.42	0.41	0.28	0.46
750-751	0.16	0.43	0.42	0.23	0.24	0.27	0.40	0.44	0.38	0.39	0.16	0.43
751-752		0.37	0.40	0.18	0.16	0.19	0.38	0.43	0.35	0.37		0.37
752-753			0.36		0.06	0.03	0.35	0.42	0.30	0.34		0.02
753-754			0.19			0.01	0.32	0.32	0.25	0.29		
>754.38								0.17	0.14			

The average depth of water over the vegetation is also considered to be a determinant factor affecting species richness, diversity, and spatial extent (Figure 5-8 and Figure 5-10). Relative to CLMBMON-10, water depth was greater at all elevation bands from 2011 to 2014 than during most of the previous six years with 2015 and 2016 similar to the pre-2011 conditions (Table 6-2). During surcharge years (2012 and 2013), water depth at 754 m ALS was < 1 m, with surcharge lasting for 32 days in 2012 and 26 days in 2013 (Table 6-1). In 2013, surcharge occurred in September only, but in 2012 surcharge occurred between June and August. Although water depth at most elevations has decreased in 2015 and 2016 relative to other years, the proportion of time that the reservoir exceeds higher elevations (i.e., those > 748 m ASL) has increased, particularly in 2016.

The interaction between depth and duration and their effects on vegetation species richness, diversity, and extent are likely more important that either one, but this has not been explicitly tested and is challenging or even impossible in the absence of an ability to manipulate any one or all of these variables. The use of GDDs as a proxy for depth and duration does provide some insight into the variable effects of reservoir operations on the vegetation communities in the drawdown zone, but is more related to timing that to depth. There does appear to be a balance between too much inundation (in terms of depth and duration) and not enough inundation, with cursory results suggesting that some inundation (or moisture) is beneficial to plant survivorship and vigor. Miller et al (2016) reported that brief periods of inundation (~ one week) did not unduly limit photosynthesis or otherwise stress the plants evaluated. Furthermore, an increase in the amount of available soil moisture following inundation may have allowed some species to extend their growing season into the fall, suggesting that in some cases the short-term benefits of brief inundation may exceed or at least equal those accruing from non-inundation.

Table 6-2: Average water depth (m) over the drawdown zone of Kinbasket Reservoir, 2005 to 2016. In 2012 and 2013 the elevation of Kinbasket Reservoir exceeded the normal operating maximum of 754.38 m ASL

Elev. (m ASL)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
741	7.20	8.93	10.11	7.81	7.62	8.09	10.32	11.28	10.52	10.06	6.94	8.60
742	6.41	8.09	9.40	7.07	6.92	7.37	9.63	10.40	9.73	9.36	6.33	7.87
743	5.66	7.31	8.68	6.31	6.29	6.63	8.83	9.61	8.93	8.54	5.48	7.07
744	4.77	6.59	7.95	5.61	5.49	5.88	8.11	8.91	8.12	7.81	4.56	6.18
745	3.96	5.78	7.20	4.97	4.87	5.18	7.37	8.00	7.20	6.98	3.67	5.33
746	3.09	4.95	6.36	4.30	4.17	4.46	6.53	7.17	6.43	6.20	2.73	4.70
747	2.43	4.10	5.56	3.54	3.49	3.70	5.75	6.40	5.58	5.41	2.02	3.96
748	1.76	3.23	4.75	2.75	2.78	2.91	4.94	5.53	4.77	4.66	1.65	3.20
749	1.08	2.35	3.86	2.16	2.01	2.08	4.12	4.60	4.05	3.83	1.10	2.38
750	0.39	1.47	3.00	1.49	1.40	1.26	3.27	3.70	3.36	2.97	0.52	1.55
751		0.63	2.10	0.75	0.84	0.57	2.43	2.78	2.62	2.12		0.71
752			1.24		0.10	0.50	1.58	1.84	1.97	1.28		0.07
753			0.78			0.00	0.68	1.23	1.25	0.41		
754			0.18				0.06	0.46	0.45			
>754.38								0.14	0.14			

6.3.1.2 Wet Stress, 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 10-2), with April 2016 being considerably warmer than all other years. Otherwise, average temperatures over the growing seasons were similar over time. Relative humidity (per cent) was also similar across all years. Total precipitation was highest in 2010 and lowest in 2009. The 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.

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 zones (elevations) 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, 2014, and 2016, 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.

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 as a function of reservoir operations (Figure 4-1), which in turn reduce the number of GDDs available to plants. By August most of the drawdown zone between 741 and 751 m ASL is under water. At this point, the proportion of growing degree days (GDD) is assumed to be slightly more than 0 per cent (Figure 6-3). Between 2006 and 2016 reservoir operations begin to affect GDDs at the lowest elevations (741 m ASL) in June and by the mid-summer growing months of July, and August, there was a substantial reduction in the proportion of available growing days in 2007, 2012, 2014, and 2016 relative to 2008 and 2010. This trend was exacerbated in 2015 and 2016 either by constantly high reservoir elevations (2015 and 2016) or the rapid filling of the reservoir (2016; Figure 4-1).

Although reservoir operations affect the number of GDDs by elevation, the increase in species richness observed at some higher elevations following the last surcharge event in 2013 may also be related, in part, to a slight increase in the GDDs available to plants in 2014, 2015, and 2016, with increases in GDDs in between June and August for elevations > 750 ASL.

		Elevation (m ASL)													
Month	Year	741	742	743	744	745	746	747	748	749	750	751	752	753	754
April	2006	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
	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
	2015	0.83	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
	2016	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	2006	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
	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
	2015	0.97	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
	2016	1.00	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
June	2006	0.47	0.53	0.63	0.77	0.87	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	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
	2015	0.00	0.00	0.10	0.17	0.27	0.33	0.53	0.80	0.97	1.00	1.00	1.00	1.00	1.00
	2016	0.00	0.10	0.20	0.27	0.37	0.63	0.83	1.00	1.00	1.00	1.00	1.00	1.00	1.00
July	2006	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.16	0.29	0.45	0.81	1.00	1.00	1.00
	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
	2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	1.03	1.03	1.03	1.03
	2016	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	1.03	1.03	1.03	1.03
August	2006	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
	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
	2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.37	0.87	1.03	1.03	1.03	1.03
	2016	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.03	1.03	1.03
September	2006	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
	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
	2015	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.83	1.00	1.00	1.00	1.00	1.00	1.00
	2016	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.90	1.00	1.00

Figure 6-3: **Proportion of growing days available during the growing season (April 1 through September 30) 2006 to 2016 for elevations between 741 and 754 m ASL. CLBMON-10 was implemented in 2007, 2008, 2010, 2012, 2014, and 2016.** 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

6.4 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 2016 (Table 6-3).

Table 6-3: 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	2016
Carex crawei	Crawe's Sedge	Red-listed	Y	Y	N	Y	N	N
Carex tonsa[1]	Bald sedge	Blue-listed	Y	N	N	Y	N	N
Eleocharis elliptica	Elliptic spike rush	Blue-listed	Y	N	Y	Y	Y	Y
Liparis loeselii	Yellow widelip orchid	Red-listed	Y	N	Y	Y	N	N
Mimulus breviflorus	Short flowered monkey flower	Red-listed	Y	Y	Y	N	N	N
Mimulus breweri	Brewer's monkey flower	Blue-listed	Y	N	Y	Y	N	N
Packera plattensis[2]	Plains butterweed	Yellow-listed	Y	Y	Y	Y	N	N
Juncus stygius[1]	Bog rush	Blue-listed	--	--	--	Y	N	N
Dryopteris cristata[1]	Crested wood fern	Blue-listed	--	--	--	Y	N	N
Muhlenbergia glomerata[3]	Marsh muhly	Blue-listed	--	--	--	--	N	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 6-3 have Committee on the Status of Endangered Wildlife in Canada (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.

7.0 CONCLUSIONS

Many of the conclusions reached in the last implementation year (Hawkes and Gibeau 2015) were supported in the current implementation year. The results of the GLMMs provide insight into the factors that influence vegetation communities in the drawdown zone of Kinbasket Reservoir. It is important to note that none of these factors is acting independently and that the interactions between the frequency, timing, duration, and depth of inundation are likely more important than any one single factor. Each of these aspects of reservoir operation influences GDDs, rates of erosion, sedimentation, wood debris accumulation and scour, wind action, but because none of these factors has been directly measured or manipulated, it is not possible to quantify the effect that changes to these factors would have on the extent and occurrence of vegetation growing in the drawdown zone of Kinbasket Reservoir. However, evidence from other work (e.g., CLBWORKS-1; Hawkes 2015) points to the benefits of wood debris removal on the establishment and development of vegetation communities and cursory data support the notion that some level of short-term inundation is potentially beneficial to plants.

Since 2007 the tendency has been to fill Kinbasket Reservoir earlier in the growing season and maintain higher elevations for longer into the year. This type of operation, coupled with an increased frequency of filling or surcharging the reservoir will likely result in a further reduction in species richness and diversity in communities situated in the upper elevation bands of the drawdown zone (i.e., those > 748 m ASL). The communities situated in the lower and mid elevation bands (i.e., < 748 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 (Figure 4-2). 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 at elevations >748 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. However, with successive years of non-filling events (i.e., 2015 and 2016), there is evidence (Miller and Hawkes, unpublished data) that several species, including herbs, grasses, and more importantly, woody stemmed species of willow and cottonwood are establishing on ground that would normally be inundated in the fall (September). These patterns of colonization are consistent with the results of CLBMON-10 and the effects of reservoir inundation on plant establishment and vegetation community development. A reduction in the frequency, timing, duration, and depth of inundation will contribute to an increase in the cover and extent of vegetation in the drawdown zone of Kinbasket Reservoir with the biggest changes occurring at higher elevations (>750 m ASL), on organic and mineral soils, and in areas devoid of wood debris.

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. Furthermore, it will likely be necessary to implement annual sampling that occurs, when possible, before and after inundation to determine if reservoir inundation affects plants growing at different elevations differently. Doing so would provide a direct measure of the effects of the timing, duration, and depth of inundation on vegetation communities in Kinbasket Reservoir.

Table 7-1 summarizes the management questions and the 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 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) results are provided

Management Question	Will MQ Be Addressed in 2016?	Current Supporting Results	Suggested Modifications to Methods Where Applicable	Sources of Uncertainty/ Limitations
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, 2014 and 21 in 2016 (DI = Disturbed was included due to the prevalence of this VCC in some areas) and the SW or Shrub-willow at higher elevations where transitional habitats exist between drawdown graminoid-dominated vegetation to upland forest. All analyses were based on the 19 communities described in 2010.	Not all areas of the drawdown zone with existing vegetation have been mapped, which may underestimate the total area of existing vegetation. It may also underestimate the number of vegetation communities that occur in the drawdown zone. If future work is considered for existing vegetation in the drawdown zone of Kinbasket Reservoir, these additional areas could be included. The results as presented in this report are unlikely to change as a result of mapping the extent of vegetation throughout the entire drawdown zone of Kinbasket Reservoir.	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	The 19 communities characterized in 2010 have monitored and the distribution of those communities relative to elevation has been described. The spatial extent is affected by reservoir operations, particularly when the reservoir exceeds full pool. Various factors interact (depth, duration, timing, GDDs, wood debris accumulation) to influence vegetation communities occurring in the drawdown zone between 741 and 754 m ASL. Specifically, species richness, diversity, and spatial extent vary relative to one or more of the factors mentioned previously.	Not all areas of the drawdown zone with existing vegetation have been mapped, which may underestimate the total area of existing vegetation. It may also underestimate the number of vegetation communities that occur in the drawdown zone. If future work is considered for existing vegetation in the drawdown zone of Kinbasket Reservoir, these additional areas could be included. The results as presented in this report are unlikely to change as a result of mapping the extent of vegetation throughout the entire drawdown zone of Kinbasket Reservoir.	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	Spatial extent varies relative to factors such as vegetation community, year, growing degree days (GDD), and water depth. Spatial extent varied significantly between communities within nine communities (WS, WB, TP, SH, RC, MA, LL, KS, CH) showing a significant increase in spatial extent while four (MC, FO, DR, and CT) showed a decrease. While taking all factors into account, the spatial extent of vegetation communities in general was positively correlated with year. The spatial extent of communities also varied with the amount of growing degree days and water depth: spatial extent decreased with GDD in June and July. Notably, spatial extent decreased with increasing water depth in July, but increased with increasing water depth in September.	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. This is because vegetation grows slowly and the duration of CLBMON-10 may not have been long enough to measure the response of vegetation to specific types of reservoir operations, specifically surcharge, which occurred in 2012 and 2013.	The longer-term effects of surcharge or repeated years of high water are likely to limit the spatial extent of existing vegetation communities. A within-year, pre- vs. post-assessment of the effects of inundation on vegetation could provide data to test this assumption. Data analyses completed under CLBMON-35 could also contribute to this assessment. The LiDAR data collected in 2014 has not been used to assess the timing, duration, frequency, and depth of Kinbasket Reservoir on existing vegetation. Given that we know the LiDAR data varies substantially from the DEM used in the assessment for CLBMON-10, it is recommended that the extent of vegetation communities and the effects of reservoir operations to those communities be reassessed relative to the LiDAR data.

Management Question	Will MQ Be Addressed in 2016?	Current Supporting Results	Suggested Modifications to Methods Where Applicable	Sources of Uncertainty/ Limitations
iv. Does the current operating regime of Kinbasket Reservoir maintain the spatial extent, structure and composition of existing vegetation communities in the draw down zone?	Yes	Current data suggest that the current reservoir operating regime (2007 - present) negatively affects species richness and diversity. Over time, there has been a six per cent increase in the spatial extent of vegetation (all landscape units and VCCs combined), and this may be related to the removal of wood debris, which has exposed some areas of the draw down zone and contributed to the establishment of vegetation. There is substantial variation in the spatial extent of vegetation within each vegetation community. The vegetation community classifications generated in 2007 have remained relatively stable over time, with little change in species composition of each community (i.e., the same dominant species can be used to define each community). The vegetation communities do partition along a gradient that is more related to successional status than species composition, with pioneering and young seral communities (e.g., LL, TP, CH) clustering together over time relative to mature seral to mature climax communities (e.g., CT, LH, and MC). The persistent partitioning of communities along a successional gradient suggests that the conditions these communities are subjected to are not conducive to succession. Although not all years and communities group together, this should not be taken as an indication that the initial classification (from 2007) was deficient; it is a reflection of the conditions under which the vegetation communities persist, which is evident with the results presented in this report.	See above - the longer term effects of the operating regime on the spatial extent of existing vegetation communities may not be realized over a 10 year period due to the relatively slow rates of vegetation succession. The predictable, yet variable manner in which Kinbasket Reservoir is managed (operating regime presents some challenges due to different operations from one year to the next. Additional sampling (within year, pre- vs. post-inundation over a one or two year period) coupled with more detailed analyses associated with CLBMON-35 will likely provide more insight into the relationships between reservoir operations and the spatial extent and species composition of exiting vegetation communities in the draw down zone of Kinbasket Reservoir.	At present it appears that most communities are persisting in the draw down. Reservoir operations do affect the number of growing degree days, which is limiting the establishment and development of vegetation communities in the draw down zone of Kinbasket Reservoir. The impacts of other non-measured factors such as rates of erosion and sedimentation related to reservoir operations and the effect on existing vegetation requires study. Similarly, the effects of wave energy (fetch, wave action) on the draw down zone at different elevations have not been studied. The relationship between wood debris accumulation and scour has been reported, but not directly studied. We know that removing wood from the draw down zone provides an opportunity for vegetation to naturally establish and develop, but not knowing the probability of wood debris accumulation or the mechanisms responsible for the inputs of wood into the system contributes to uncertainty regarding how the operating regime of Kinbasket Reservoir affects the spatial extent and species composition of exiting vegetation communities in the draw down zone. We also know that there are elements of the natural environment that are likely to influence vegetation growing in the draw down zone and that are not related to reservoir operations (e.g., debris flows, avalanches, and fire). Other influences (e.g., erosion, sedimentation, wood debris deposition, and wave energy) are related to reservoir operations, but the relative effect of these natural and reservoir-related factors were not studied under CLBMON-10. Some (e.g., wood debris deposition and perhaps erosion in some places) could be assessed under CLBMON-35 or through a review of the CLBMON-10 and associated data with an aim to address as many of these uncertainties as possible.

Management Question	Will MQ Be Addressed in 2016?	Current Supporting Results	Suggested Modifications to Methods Where Applicable	Sources of Uncertainty/ Limitations
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 w ater and surcharge on the reduction of factors such as GDDs, w hich affects the specie richness, diversity and spatial extent of vegetation in the draw down zone, a reduction in the maximum elevation and duration of inundation w ould function to maintain and possibly expand existing vegetation at higher elevations (i.e., those >748 m ASL). It may be possible to implement physical w orks to either protect or create habitats in the draw down zone, w hich could lead to the maintenance of vegetation communities. A trial w as implemented via CLBWORKS-1 in 2015 and additional w orks are under consideration. These efforts are small-scale projects that w ill not result in the revegetation of large areas (10's or even 100's of hectares) of the draw down zone.	See above.	The vegetation communities have developed in the draw dow n zone under various operating conditions and appear to be somew hat adapted to this variation. To maintain or increase the spatial extent of vegetation betw een 741 and 754 m ASL w ould require filling the reservoir to < 748 to afford the vegetation at higher elevations time to develop. The current operation of the reservoir w ill probably contribute to a further reduction in species richness and may affect the spatial extent of vegetation over time.

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. An assessment of the mechanisms responsible for the input of wood debris into Kinbasket reservoir is recommended. There are several likely (and known) mechanisms such as debris flows and avalanches, but the extent to which erosion as a result of reservoir operations contributes to the input of wood is unknown. Knowing how wood enters the system, the frequency of the occurrence, and the volume of wood entering the system would be very informative with respect to future physical works and the long-term viability of vegetation in some parts of the drawdown zone where wood debris is known to accumulate (e.g., Packsaddle Creek, Canoe Reach, parts of Bush Arm);
3. An additional year of photo acquisition is recommended. The tendency for the reservoir to be managed deeper and longer is likely to have effects on existing vegetation. Acquiring another set of photos will enable a final assessment of these effects on vegetation, and pending the filling of the reservoir in 2017, will also provide the ability to assess the effects of a full-pool operation on the physical works and log booms that have been installed in Canoe Reach and at the Bush Arm Causeway;
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, 2014, and 2016) 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; and
6. Obtain quantitative data on soil moisture and soil organic carbon (e.g., 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).

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.

BC Ministry of Forest and Range and BC Ministry of Environment. 2010. Land Management Handbook 25. Field manual for describing terrestrial ecosystems, 2nd edition. Province of British Columbia, Research Branch, BC Ministry of Forests and Range, Victoria, BC.

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

Carslaw, D.C. and K. Ropkins, 2012. openair — an R package for air quality data analysis. Environmental Modelling & Software. Volume 27-28, pp. 52–61.

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.

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. 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., 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., 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.

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.

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.

Miller, M.T., J.E. Muir, P. Gibeau, and V.C. Hawkes. 2015. CLBMON-33 Arrow Lakes Reservoir Inventory of Vegetation Resources. Annual Report – 2014. LGL Report EA3545. Unpublished report by LGL Limited environmental research associates, Sidney, BC, for BC Hydro Generations, Water License Requirements, Castlegar, BC. 56 pp + Appendices

Miller, M.T., P. Gibeau, and V.C. Hawkes. 2016. CLBMON-12 Arrow Lakes Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis. Annual Report – 2015. LGL Report EA3545. Unpublished report by Okanagan Nation Alliance, Westbank, BC, and LGL Limited environmental research associates, Sidney, BC, for BC Hydro Generations, Water License Requirements, Castlegar, BC. 55 pp + Appendices.

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.

Pinheiro, J. 2017. Package 'nlme'. https://cran.r project.org/web/packages/nlme/nlme.pdf

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.

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.

Zuur, A., E.N. Ieno, N. Walker, A.A. Saveliev, and G.M. Smith. 2009. Mixed Effects Models and Extensions in Ecology in R. Statistics for Biology and Health, DOI 10.1007/978-0-387-87458-6.

10.0 APPENDICES

10.1 Appendix A: Annual Sampling Summaries

10.1.1 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.

10.1.2 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.

10.1.3 Year 4 – 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.

10.1.4 Year 6 – 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.

10.1.5 Year 8 – 2014

Field sampling in 2014 followed the methods used in previous years. A total of 98 transects were sampled representing 14 vegetation communities and 12 landscape units. Aerial photos were captured digitally in 2014 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 2014. The spatial extent of mapped vegetation communities differed significantly from 2007, but not from 2012. Differences between 2007 and 2014 were attributed to mapping errors made in 2007 and refinements to the vegetation polygons in subsequent years. Species constancy was relatively low at 24 per cent for repeat transects and 23 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.

10.2 Supporting Results

Species Constancy

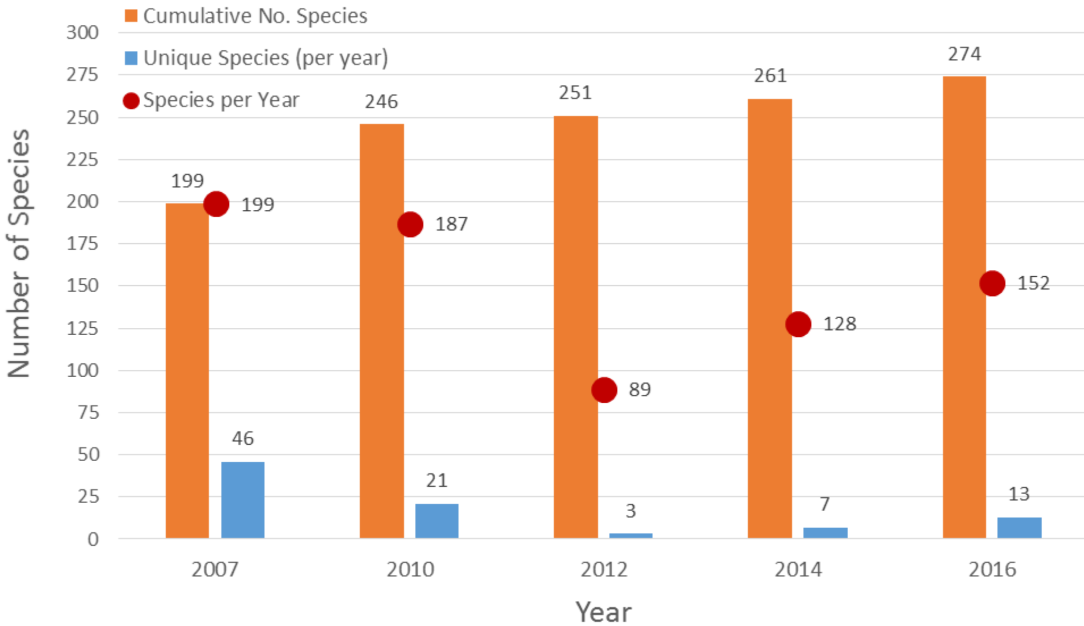

Figure 10-1: The cumulative number of vegetation species detected in the drawdown zone of Kinbasket Reservoir since 2007. The number of unique species and total number of species detected per year of sampling are also shown.

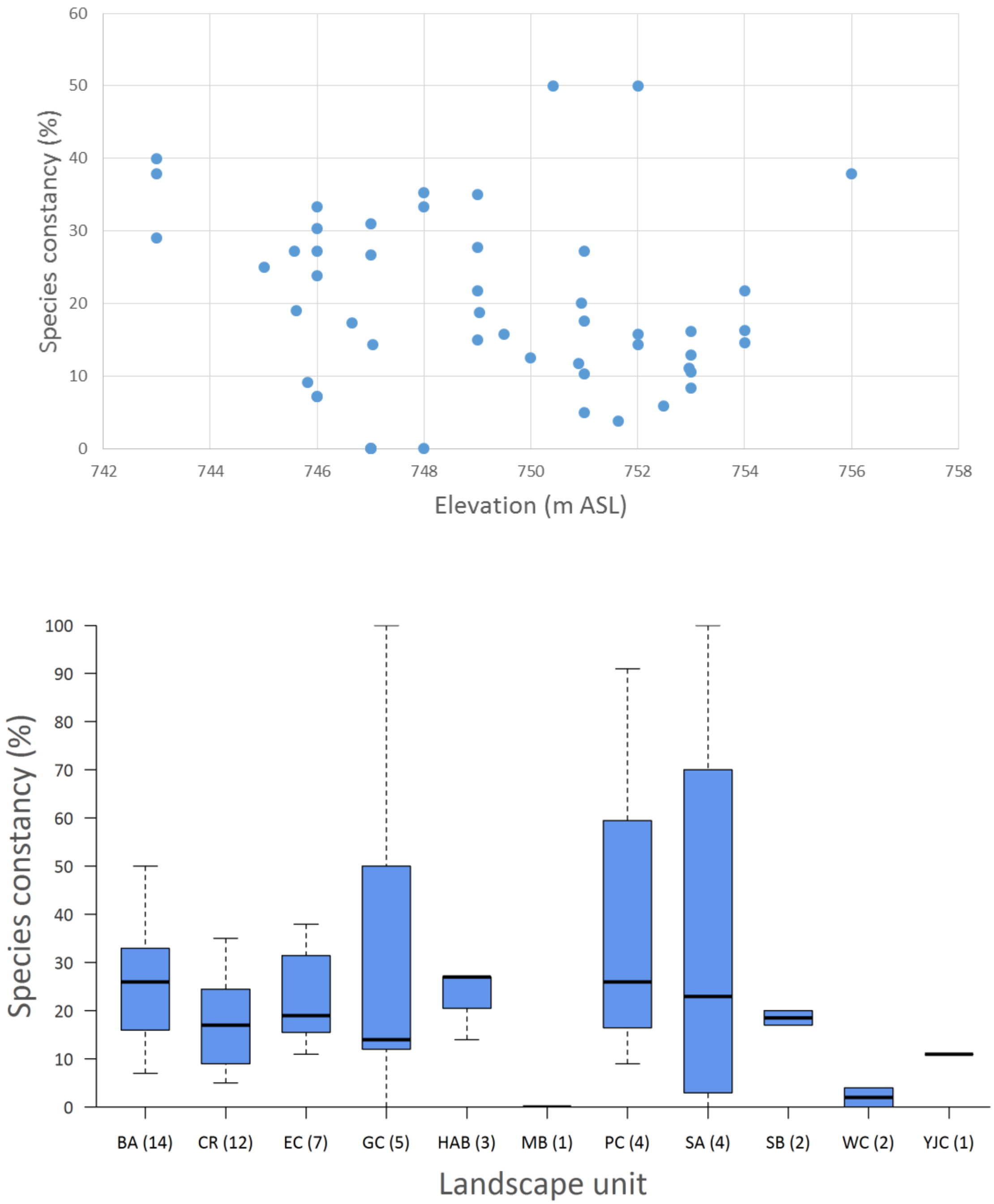

Figure 10-2. Per cent species constancy relative to elevation (top) and landscape unit (bottom). BA = Bush Arm, CR = Canoe Reach, EC = Encampment Creek, GC = Grouse Creek, HAB = Hugh Aan Bay; MB = Mount Blackman; PC = Ptarmigan Creek; SA = Sullivan Arm; SB = Sprague Bay; WC = Windfall Creek; and YJC = Yellowjacket Creek. Numbers in parentheses are the number of transects

Species Richness and Diversity relative to Landscape Unit and Time

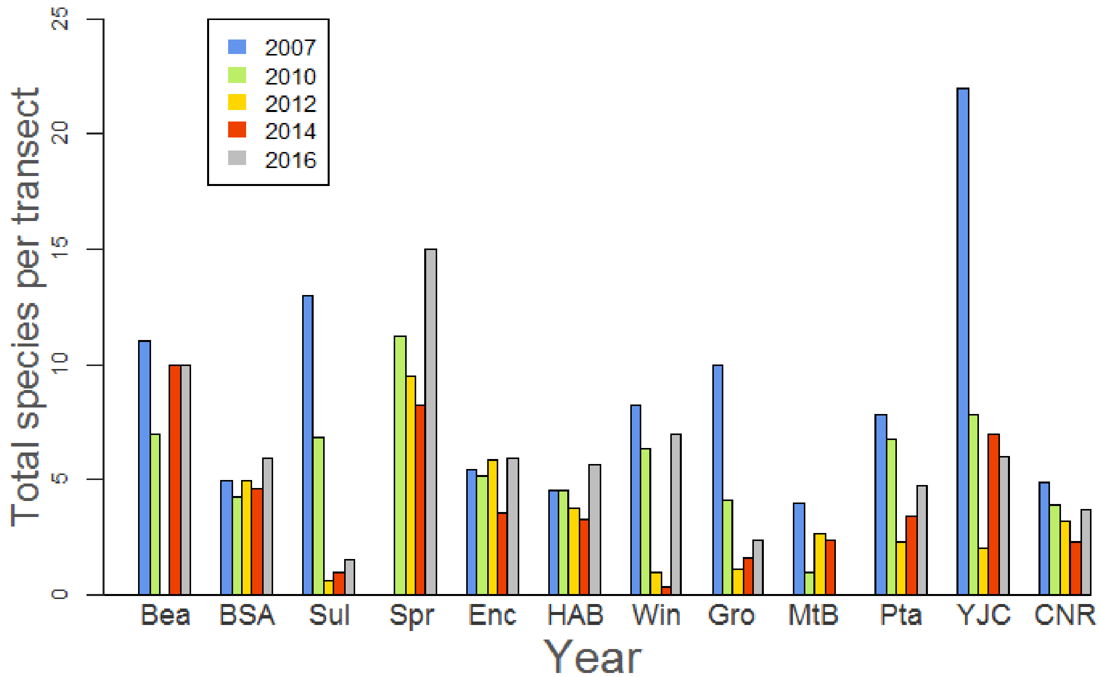

Figure 10-3: Total species richness per landscape unit corrected by sampling effort (number of transects) per landscape unit in 2007, 2010, 2012, 2014, and 2016 in Kinbasket Reservoir. Landscape units were ordered from south to north.

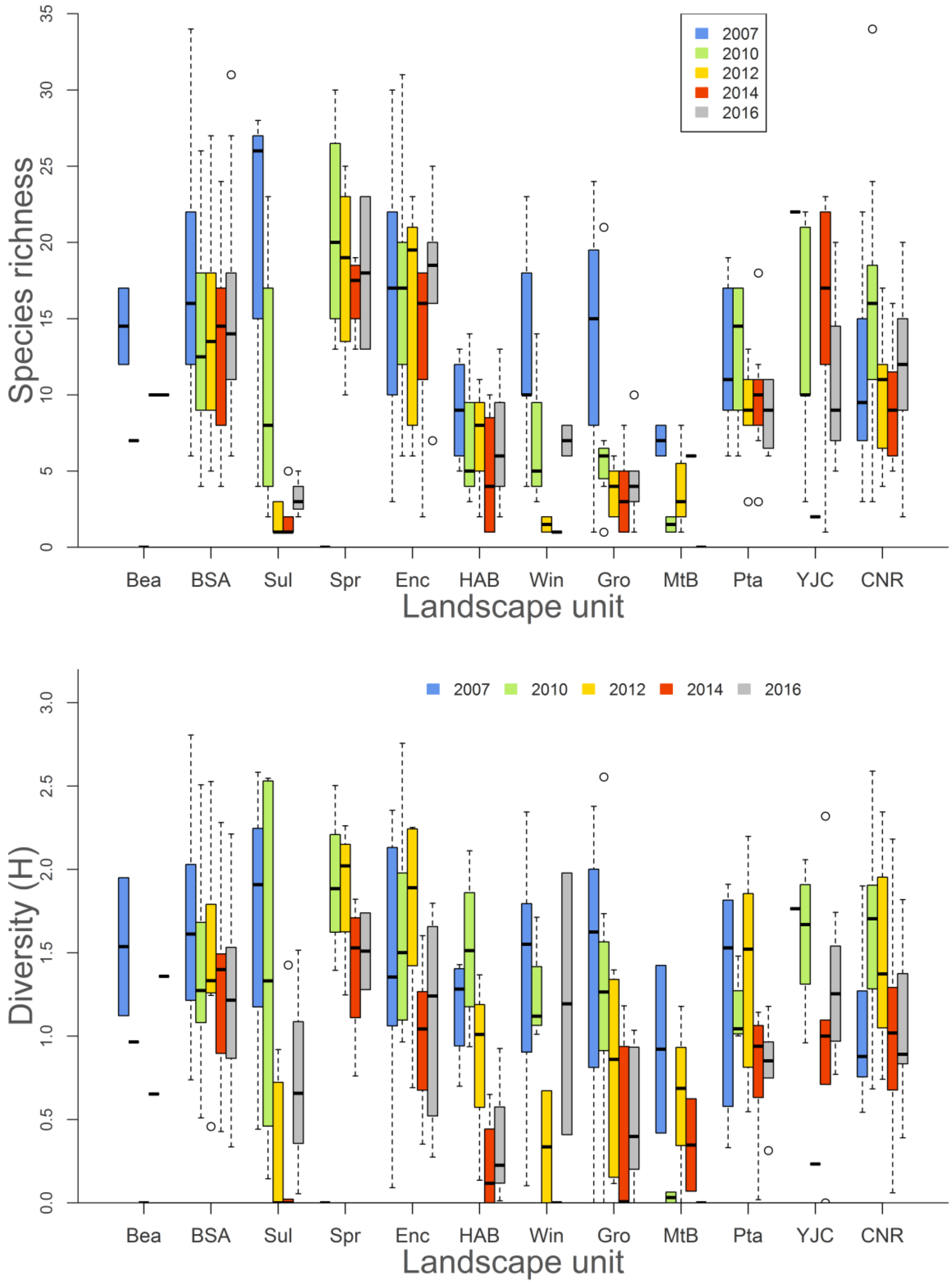

Figure 10-4: Species richness (top panel) and diversity (Shannon's H, bottom panel) per transect in each landscape unit in 2007, 2010, 2012, 2014, 2014, and 2016. Landscape units are ordered from south to north in Kinbasket Reservoir

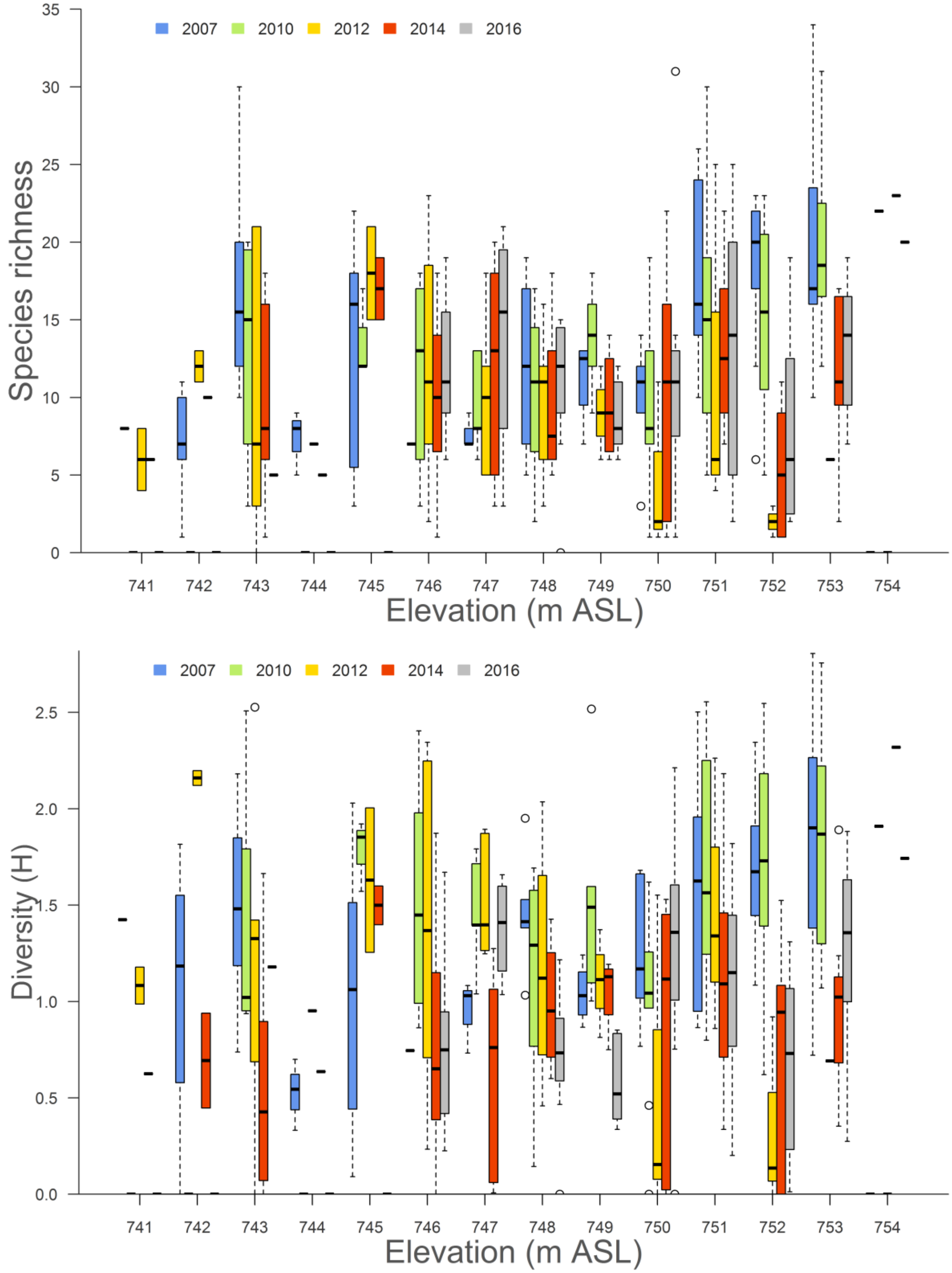

Figure 10-5: Species richness (top) and diversity (Shannon's H) of vegetation per transect in relation to elevation, over time.

Table 10-1: Summary statistics associated with the GLMMs and wald tests associated with Figure 5-10. Critical level of alpha was set top 0.1 for tests of significance

Factor	Value	Std.Error	DF	t-value	p-value
Year	0.037767	0.0304617	1244	1.23983	0.2153
VCCBR	0.381511	0.2565859	1244	1.48688	0.1373
VCCBS	0.472247	0.429344	1244	1.09993	0.2716
VCCCH	0.550723	0.1272052	1244	4.32941	0
VCCCT	-0.536957	0.1521406	1244	-3.52935	0.0004
VCCDR	-0.297318	0.1356964	1244	-2.19105	0.0286
VCCFO	-0.291615	0.1567247	1244	-1.86068	0.063
VCCKS	0.373625	0.1263167	1244	2.95784	0.0032
VCCLL	1.052035	0.1705872	1244	6.16714	0
VCCMA	1.239749	0.3345528	1244	3.70569	0.0002
VCCMC	-0.724811	0.3007908	1244	-2.40968	0.0161
VCCRC	1.456772	0.3327625	1244	4.37781	0
VCCSH	0.811189	0.2105256	1244	3.85316	0.0001
VCCTP	0.436902	0.1951315	1244	2.23901	0.0253
VCCWB	0.873358	0.1941726	1244	4.49785	0
VCCWS	0.438376	0.2211445	1244	1.98231	0.0477
GDD.May	-0.065529	0.063682	1244	-1.029	0.3037
GDD.Jun	-0.250489	0.0849193	1244	-2.94972	0.0032
GDD.Jul	-0.240064	0.0794392	1244	-3.02199	0.0026
GDD.Aug	0.008154	0.0831517	1244	0.09806	0.9219
GDD.Sept	-0.025955	0.0606752	1244	-0.42777	0.6689
Depth.Jul	-0.546677	0.1755705	1244	-3.11372	0.0019
Depth.Sept	0.309078	0.1423894	1244	2.17065	0.0301

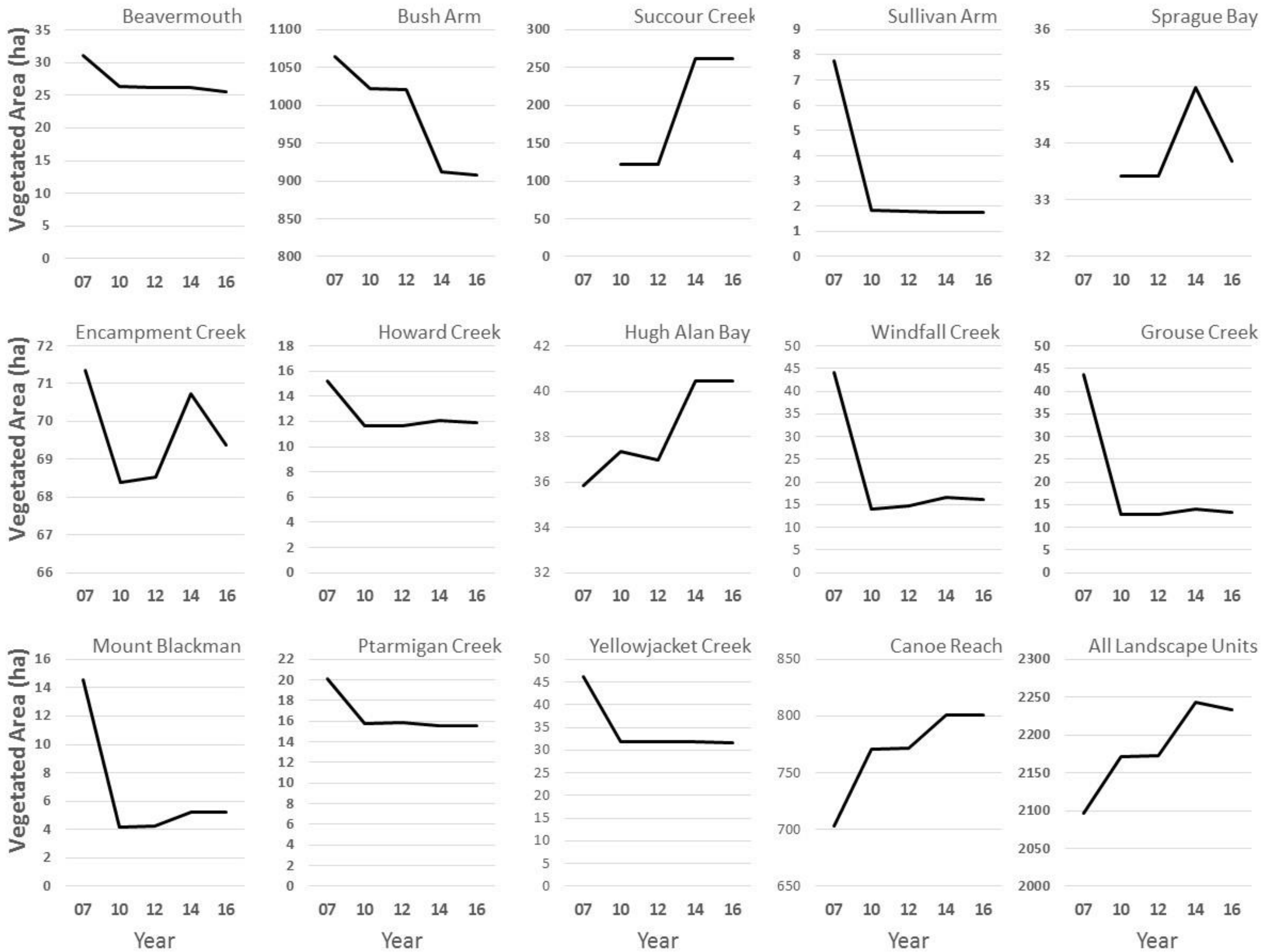

Figure 10-6: The extent of vegetation mapped in each landscape unit and overall between 2007 and 2016. Landscape units are ordered from south (top left panel) to north (bottom right panel; Canoe Reach). The extent of vegetation mapped for all landscape units combined is provided in the bottom right panel. Note varying scales on the y-axis of each panel. Note that y-axis values differ by landscape unit.

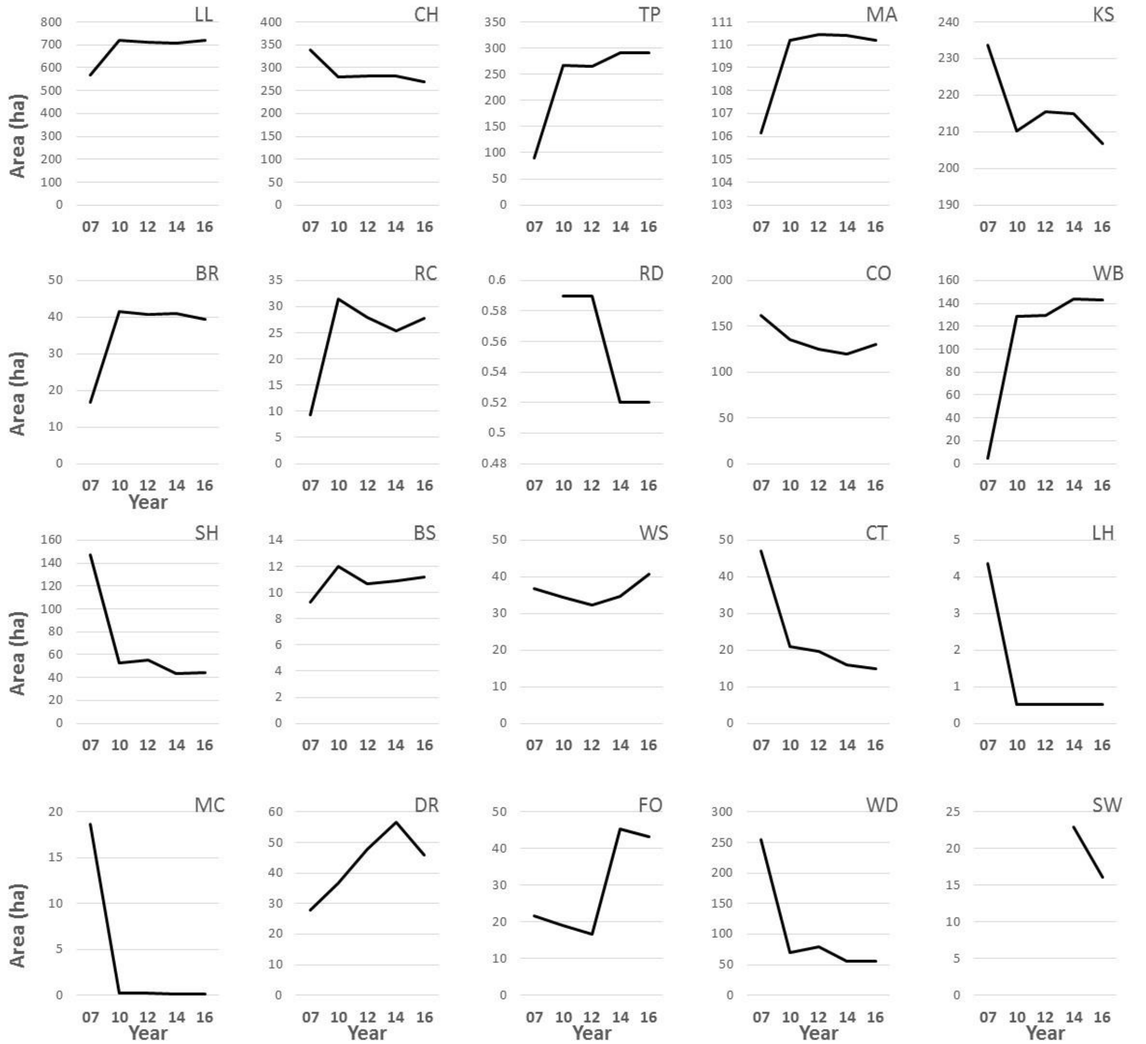

Figure 10-7: The extent of vegetation mapped for each vegetation community between 2007 and 2016. Vegetation communities are ordered from early pioneering to late seral stages in Kinbasket Reservoir. Note that y-axis values differ by vegetation community.

Table 10-2: Average temperature (°C), relative humidity (%) and precipitation (mm) associated with the exposed elevation bands in April through September 2007 – 2016. Sampling for CLMON-10 occurred in 2007, 2008, 2010, 2012, 2014, and 2016

	Air Temperature (°C)									
Month	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
April	4.27	2.79	4.37	5.30	3.18	4.92	4.22	4.83	5.39	8.70
May	10.36	10.90	9.16	9.11	9.93	9.29	11.52	9.96	12.09	11.32
June	13.75	13.35	13.88	13.67	13.60	12.82	15.17	13.72	16.28	14.42
July	18.38	15.47	18.03	16.43	14.23	17.41	16.76	18.47	17.50	16.07
August	14.02	15.09	15.94	14.69	14.44	15.81	16.34	16.70	15.50	16.71
September	9.62	10.02	12.74	9.49	12.07	11.63	12.99	11.17	9.62	9.97
	Relative Humidity (%)									
Month	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
April	71.17	64.87	59.91	64.37	66.87	75.38	64.61	65.57	62.18	62.38
May	61.47	63.64	60.78	60.29	66.48	60.68	61.92	63.94	56.25	61.98
June	69.77	65.41	57.84	63.83	69.86	73.65	65.19	61.59	60.78	67.06
July	62.77	66.17	61.75	61.77	76.37	70.03	62.60	57.26	65.18	73.31
August	74.56	70.19	65.63	72.70	74.62	72.69	72.38	68.05	70.42	68.63
September	77.30	76.97	71.19	84.88	75.17	74.11	71.96	75.80	80.02	77.07
	Precipitation (mm)									
Month	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
April	79.82	26.74	34.37	58.80	37.80	166.00	85.80	50.60	81.00	20.40
May	54.47	39.08	72.62	49.80	63.60	31.20	109.00	96.60	57.80	117.20
June	84.38	73.28	53.60	120.60	131.60	243.00	43.80	88.20	81.20	83.80
July	67.13	104.42	70.20	94.80	182.80	181.00	69.00	61.80	102.00	103.60
August	103.21	113.19	46.60	161.60	77.60	72.20	136.00	78.20	178.20	103.00
September	89.24	70.25	78.20	295.00	136.00	34.60	95.00	105.80	139.40	92.80
Total	478.25	426.96	355.59	780.60	629.40	728.00	538.60	481.20	639.60	520.80