Columbia River Project Water Use Plan

Kinbasket and Arrow Reservoirs Revegetation Management Plan

Kinbasket Inventory of Vegetation Resources

Implementation Year 1

Reference: CLBMON-57

Study Period: 2018

LGL Limited environmental research associates
Sidney, BC

December 19, 2019

EA3896

CLBMON-57 Addendum #1 to CLBMON-10 Kinbasket Reservoir Inventory of Vegetation Resources - Mica Project Units 5 and 6 Addendum




2018
Report

BC Hydro

Prepared for

Water Licence Requirements
6911 Southpoint Drive
Burnaby, BC

BC Hydro Reference No. Q7-7123

Prepared by

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

Michael T. Miller, Ph.D.

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 15 2019

LGL LIMITED
environmental research associates

Suggested Citation

Hawkes, V.C., M.T. Miller, and P. Gibeau. 2019. CLBMON-57 Addendum #1 to CLBMON-10 Kinbasket Reservoir Inventory of Vegetation Resources - Mica Project Units 5 and 6 Addendum. Annual Report–2018. LGL Report EA3896. Unpublished report by LGL Limited environmental research associates, Sidney, B.C., for BC Hydro Generations, Water License Requirements, Burnaby, B.C. 52 pp + Appendices.

Cover photos

From left to right: Common Horsetail Community in Bush Arm; wood 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

2018 marked the seventh year of a monitoring study of the vegetation communities occurring in the drawdown zone of Kinbasket Reservoir between 741 and 754 m 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.

CLBMON-57, the subject of this report, is a one-year addendum to CLBMON-10 implemented in 2018 to provide additional information on how shoreline vegetation responds to reservoir operations over time. Specifically, this program assesses the vegetation effects of increased water levels in Kinbasket Reservoir on the upper drawdown zone (i.e., 752 to 754 m ASL) resulting from the operation since 2016 of Mica Units 5 during the summer refill period, and whether changes to the reservoir's operating regime may be required to maintain or enhance existing vegetation and the ecosystems it supports.

We conducted this assessment in two ways. First, we used a retrospective analysis of vegetation and operational trends occurring over the course of the monitoring period (2007-2018) to address the existing CLBMON-10 management questions pertaining to vegetation cover, composition, and extent. Study design and sampling methodology followed that of previous implementation years (e.g., Hawkes and Gibeau 2017). Second, we used forward-looking simulations to model the predicted impacts of increasing reservoir levels by 60 cm in 3 out 10 years (the anticipated hydroregime change associated with Mica 5). Three different operational scenarios were modeled using simulations. The three scenarios differed with respect to the timing and duration of the 60 cm increase in reservoir level. Each scenario was applied to the following vegetation parameters: total herb cover; total shrub cover; cover and frequency of sedges (*Carex* spp.); and cover and frequency of willows (*Salix* spp.). Simulation results were then compared to each other and to baseline models for each parameter.

21 vegetation community types (VCCs) have been delineated, and 19 VCCs have been 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 (~ 9 per cent) increase in the total extent of vegetation in the drawdown zone, which is related (in part) to the reduction in wood debris deposits in the drawdown zone (from ~ 254 ha in 2007 to ~ 56 ha in 2016). However, this slight increase in vegetation cover at the landscape level has been coupled with a decrease in species richness and diversity over time at the site level. In addition to wood debris accumulations, various factors (depth, duration, and timing of inundation; growing degree days [GDD]; slope; and substrate) interact to influence richness and diversity. Specifically, richness and diversity decrease as slope increases; increase with elevation; and increase with increased GDD in late summer (August and September). Richness and diversity also increase on sites with rich organic (as opposed to coarse well-drained) substrates.

The diversity of communities within each landscape unit, as well as the relative distributions of communities within landscape units, has remained more or less stable with time. This, in combination with the slight but incremental increases over time in the total spatial extent of mapped vegetation, implies that the current operating regime is succeeding in maintaining the general character, composition, and extent of vegetation at the landscape scale. Annual reservoir operations do affect the growing time available to plants, particularly when full pool is exceeded,

and thus will likely continue to limit the further establishment and development (and species richness) of vegetation communities in the drawdown zone of Kinbasket Reservoir.

With respect to effects on vegetation from future operation of Mica Generating Unit 5, simulations models did not detect any substantive effects on herb or shrub cover, or on sedge or willow frequencies, from increasing reservoir elevations by 60 cm in 30% of years. Acknowledging that the available data set is limited in terms of size and scope, it appears that any potential vegetation impacts associated with a semi-periodic increase in reservoir levels by 60 cm are likely to be swamped by the environmental noise of much larger inter-annual fluctuations in inundation depth and duration.

It should be noted that since the 2016 entry in operation of Mica 5, reservoir maximums have remained comparatively low relative to those experienced during the decade prior. This means that a large segment of drawdown vegetation has not yet been subjected to any additional inundation cycles directly (or indirectly) ascribable to Mica 5 operation. For this reason, predictions of minimal to no effect based on data simulations should be verified through further post-entry monitoring.

The status of CLBMON-10/57 after 2018 with respect to the management questions is summarized in tabular form (below).

Management Question (MQ)	Summary of Key Results
1. What are the existing riparian and wetland vegetation communities in the Kinbasket Reservoir drawdown zone between elevations 741 m to 754 m?	<u>Summary Findings</u> 21 community types, ranging from low-elevation, early pioneer to high-elevation, established shrubland, have been delineated: 18 in 2007 and 2008; 19 in 2010, 2012, 2014; and 21 in 2016 and 2018. <u>Sources of Uncertainty/ Limitations</u> 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. <u>Comments</u> 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.
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?	<u>Summary Findings</u> The most speciose sites tended to be associated with the Toad rush–Pond water-starwort (TP), Marsh cudweed–Annual hairgrass (MA), Kellogg's Sedge (KS), Woolgrass–Pennsylvania buttercup (WB), Buckbean–Slender sedge (BS), and Willow–Sedge wetland (WS) community types. The Common horsetail (CH), Swamp horsetail (SH), and Driftwood (DR) tended to occupy the lower end of the richness spectrum. However, species richness and diversity of individual transects varied among vegetation communities and years. Richness and diversity have decreased with time during the monitoring period. The most extensive VCCs in the drawdown zone are Lady's thumb—Lamb's quarter and Common horsetail. The total spatial extent of mapped vegetation was maximal at an elevation of 745 m ASL in Kinbasket Reservoir in 2018, with ~ 180 ha, and lowest at an elevation of 754 m ASL, with ~ 110 ha. This contrasts slightly with 2016, when spatial extent peaked at 743 m ASL at ~ 195 ha. Spatial extents of the top elevation bands (752-754 m ASL) also declined slightly relative to 2016. The number of VCCs mapped peaked (n = 20) at an elevation of 752 m ASL. Elevations below 744 m had fewer than 12 VCCs, and the lowest elevation (741 m) had only eight VCCs. Since 2007, the total spatial extent of mapped vegetation in the drawdown zone of Kinbasket Reservoir has increased by ~ 9 per cent (~ 178 ha), although some individual landscape units have experienced a decreasing trend over that time. The total spatial extents of the mapped VCCs also varied over time. Over the monitoring period, VCCs could be generally characterised as either: 1) stable over time (n = 2); 2) increasing then stable (n = 7); 3) decreasing then stable (n = 7); or 4) fluctuating (n = 5). Since 2010, six VCCs have increased by 10 per cent or more (MA, WB, WS, CT, DR, and FO), seven have decreased by 10 per cent or more (BR, RC, RD, CO, SH, MC, and WD), and six have not changed (LL, CH, MA, KS, BS, and LH). <u>Sources of Uncertainty/ Limitations</u> 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. <u>Comments</u> 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

Management Question (MQ)	Summary of Key Results
	drawdown zone of Kinbasket Reservoir.
3. How do spatial extent, structure and composition of vegetation communities relate to reservoir elevation and site conditions (aspect, slope and soil drainage)?	<u>Summary Findings</u> Spatial extent, structure, and composition are affected by reservoir operations, particularly when the reservoir exceeds full pool. Various factors interact (depth, duration, timing, growing degree days, wood debris accumulation) to influence vegetation communities in the drawdown zone between 741 and 754 m ASL. Specifically, species richness and diversity decrease as slope increases; increase with elevation; and increase with increased growing degree days (GDD) in late summer (August and September). Richness and diversity also increase on sites with rich organic (as opposed to coarse well-drained) substrates. Herb cover in the upper elevation bands (> 752 m ASL) decreases with increasing depth of inundation and increased GDD in July and August, but increases with increasing September GDD (i.e., with increased exposure and/or warmth during this month); and shrub cover decreases with increased duration of inundation and increases with increased July GDD. Over time, vegetation spatial extents have varied relative to community type, year (increasing with time), and elevation (maximal at mid-elevations). Two VCCs (TP and CH) showed a significant increase in spatial extent compared to the CO community, whereas five (WD, SH, LH, FO, and DR) showed a significant decrease in spatial extent compared to CO. The spatial extent of VCCs in general was positively correlated with inundation duration but decreased significantly with water depth. Spatial extent increased with increasing GDD in May and August but decreased with increased September GDD. <u>Sources of Uncertainty/ Limitations</u> 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-10/57, 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. <u>Comments</u> 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-10/57 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.
4. Does the current operating regime of Kinbasket Reservoir, including any changes due to entry in operation of Mica 5, maintain the spatial extent, structure and composition of existing vegetation communities in the drawdown zone?	<u>Summary Findings</u> Current data suggest that the current reservoir operating regime (2007 - present) negatively affects species richness and diversity. However, over time, there has been a nine per cent increase in the spatial extent of vegetation (all landscape units), 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. At present it appears that most communities are persisting in the drawdown. Reservoir operations do affect the number of growing degree days, which is likely limiting the further establishment and development of vegetation communities in the drawdown zone of Kinbasket Reservoir. That said, modeling results imply that there is a balance between too much inundation (in terms of depth and duration) and not enough inundation. This idea is supported by cursory results from a fall survey in 2015 suggesting that some mid-summer inundation may be beneficial, and even critical, to plant survivorship and vigor. With respect to effects on vegetation from future operation of Mica Generating Unit 5, simulations models did not detect any substantive effects on herb or shrub cover, or on sedge or willow frequencies, from increasing reservoir elevations by 60 cm in 30% of years. Acknowledging that the available data set is limited in terms of size and scope, it appears that any potential vegetation impacts associated with a semi-periodic increase in reservoir levels by 60 cm are likely to be swamped by the environmental noise of much

Management Question (MQ)	Summary of Key Results
	larger inter-annual fluctuations in inundation depth and duration. <u>Sources of Uncertainty/ Limitations</u> Since the 2016 entry in operation of Mica 5, reservoir maximums have remained comparatively low relative to those experienced during the decade prior. This means that a large segment of drawdown vegetation has not yet been subjected to any additional inundation cycles directly (or indirectly) ascribable to Mica 5 operation. 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 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. <u>Comments</u> 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 variable manner in which Kinbasket Reservoir is managed (operating regime) from year to year presents many intractable challenges for hypothesis testing. Forthcoming analyses associated with CLBMON-35 (Vegetation Responses to Inundation) should 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.
5. Are there operational changes that can be implemented to maintain existing vegetation communities at the landscape scale more effectively?	<u>Summary Findings</u> Given the effects of high water and surcharge on the reduction of factors such as GDD, 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. <u>Sources of Uncertainty/ Limitations</u> 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. <u>Comments</u>

Management Question (MQ)	Summary of Key Results
	See above.

KEYWORDS: Kinbasket Reservoir; Mica 5/6; 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 Engineering, and David Polster of Polster Environmental. Sergei Yazvenko (LGL), Jeremy Gatten (LGL), and Ryan Batten collected field data. Terra Remote Sensing acquired the digital aerial imagery and produced the orthorectified imagery in 2018. 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. Yellowhead Helicopters Ltd. (Valemount BC) provided helicopter services in 2018.

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1.0 INTRODUCTION

BC Hydro has undertaken studies related to vegetation in the drawdown zones of Kinbasket Reservoir since 2007. These projects were designed to study the effects of reservoir operations on existing vegetation (CLBMON-10) and to assess the effectiveness of revegetation efforts (CLBWORKS-1 and CLBMON-9). CLBMON-10 also undertook to test the key assumption that the current operating regime can continue to maintain, in the absence of operational changes, existing riparian and wetland vegetation communities and associated ecosystems at the landscape scale (BC Hydro 2007). CLBMON-10 was implemented between 2007 and 2016 and the results of that work are summarized in Hawkes and Gibeau (2017).

CLBMON-57 (BC Hydro 2012) is a one-year extension to CLBMON-10 that was initiated following the environmental assessment process for the Mica 5 and 6 generation upgrade project. The MCA 5/6 Consultative Committee was concerned that increases in reservoir elevation resulting from future operations of Units 5 and 6 during the summer refill period could negatively impact vegetation in the Kinbasket Reservoir drawdown zone. A recommendation was made to augment the existing CLBMON-10 program with a modelling exercise to simulate the effects of increased water levels on the upper elevation band (i.e., 753 to 754 m ASL), with the addition of one extra year of vegetation inventory post-Mica 5 in-service date (BC Hydro 2012). This additional year of monitoring (2018) used the same methodological approach as CLBMON-10 to provide information on how vegetation communities respond to 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 ecosystem it supports.

2.0 OBJECTIVE, MANAGEMENT QUESTIONS, AND HYPOTHESES

2.1 Objective and Scope

The objective of this addendum to the Kinbasket Reservoir Vegetation Inventory is to add one more year of data collection to document and quantify the landscape-level responses of existing riparian and wetland vegetation communities to the operating regime of the reservoir, and to thus reduce the chance of Type II error in testing hypotheses about effects of Mica Generating Unit 5 on drawdown zone vegetation.

Specifically, the study aims to model the effects on upper zone vegetation of increasing reservoir levels by 60 cm in 30% of years through the operation of Mica 5. The study will also:

- Continue to spatially delineate riparian and wetland vegetation communities within the drawdown zone;
- Characterize the structure and composition (distribution and diversity) of vegetation communities in the drawdown zone in 2018;
- Assess whether there are changes in the spatial extent, structure and composition of the vegetation communities in the Kinbasket drawdown zone over the whole monitoring period (including that covered by CLBMON-10);

- Assess whether observed changes in vegetation spatial extent, structure and composition are attributable to the operating regime of Kinbasket Reservoir; and
- Provide information on the effectiveness of the operating regime at maintaining the spatial extent, structure and composition of the vegetation communities in the drawdown zone at the landscape level.

2.2 Management Questions

The primary management questions to be addressed by CLBMON-57 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, **including any changes due to entry in operation of Mica 5**, 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: There are no significant changes in existing vegetation communities at the landscape scale in the drawdown zone of Kinbasket Reservoir over the monitoring period.

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

H_{0B}: There are no significant changes 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 operating regime for Kinbasket Reservoir, including any effects of entry in operation of Mica 5. The decision of the WUP CC to support the regime was based on the assumption that existing vegetation conditions could be maintained over the long term. Inferences from this study will provide an assessment of the effectiveness of the operating regime to maintain existing riparian and wetland vegetation communities and associated ecosystems at the landscape scale. Furthermore, by improving the understanding of how vegetation responds to long-term variations in water levels, the program will provide information to support future decision-making around maintaining the operating regime or modifying operations through adjusting minimum or maximum elevations to maintain and enhance vegetation communities in the drawdown zone of Kinbasket Reservoir.

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.

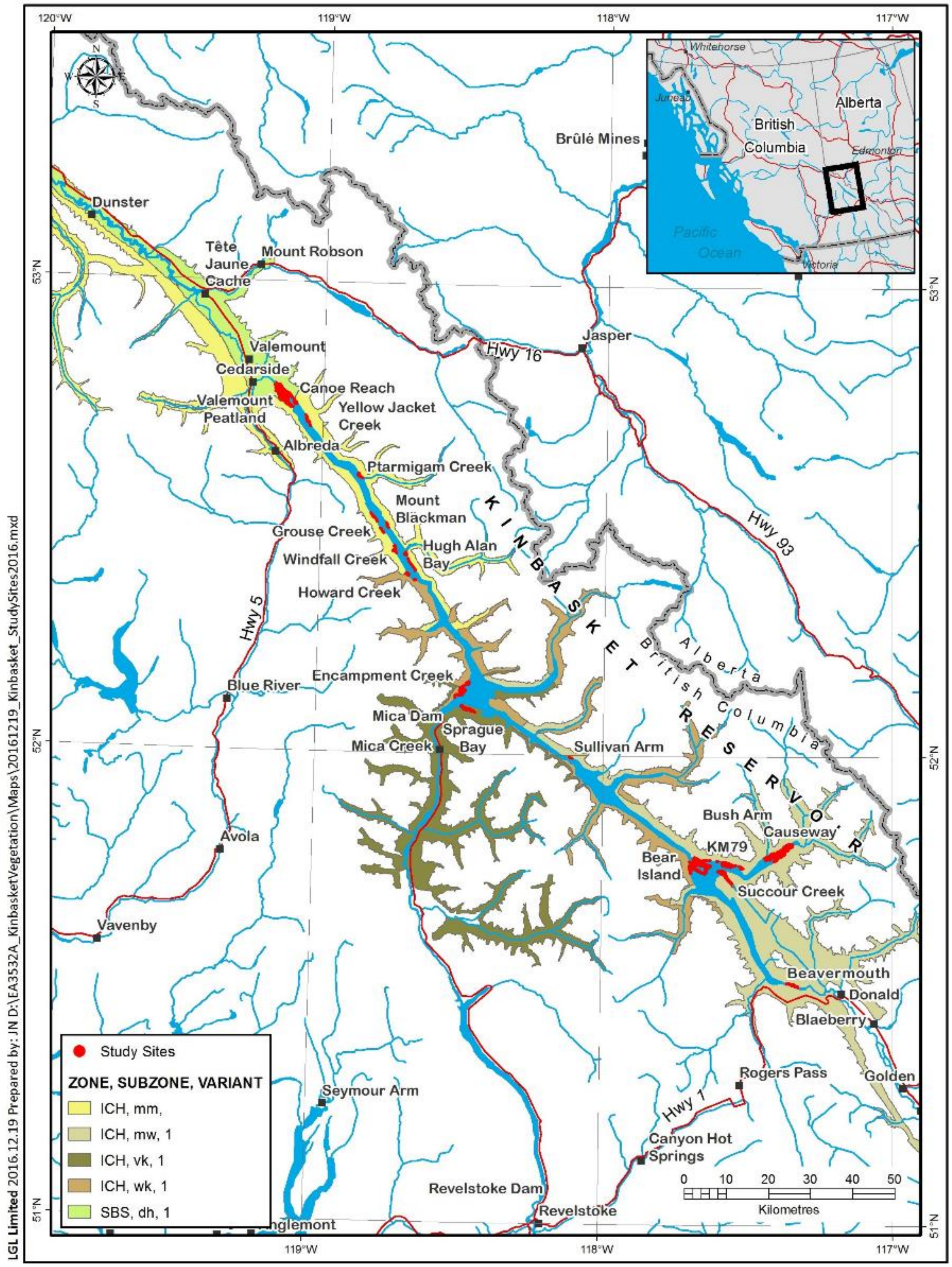


Figure 3-1: Location of Kinbasket Reservoir and vegetation sampling locations (red). Landscape unit names (e.g., Beavermouth, Encampment Creek) were assigned to each area sampled in 2007. Red areas also denote the locations of aerial photograph acquisition

3.1 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.

3.2 Climate[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

[2] From BC Hydro (2007) after BC Hydro (1983).
[3] From BC Hydro 2007 after BC Hydro 1983.

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

4.1 Background

CLBMON-10/57 was initiated in 2007 with field sampling and aerial photography acquisition in years 1, 2, 4, 6, 8, 10, and 12 (2007, 2008, 2010, 2012, 2014, 2016, and 2018). 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, species composition, 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 wood debris removal);
2. the cumulative (temporal) effects of the operating regime;
3. Wet stress and dry stress (periods of inundation and exposure); and,
4. Non-reservoir effects (e.g., wildlife use, human-related impacts; environmental conditions).

The following specific questions were addressed:

1. Did the composition and/or spatial configuration of vegetation communities within each elevation strata of the drawdown zone change over a 12-year period?
2. If a change was detected, could it be attributed to the current operating regime of the reservoir? Specifically, could it be attributed to inundation depth, frequency and duration (while controlling for potentially confounding variables such as climate, human and wildlife use, and topography)?

The results of each prior year 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, 2017). A brief overview of 2007, 2008, 2010, 2012, 2014, and 2016 is provided in Section 9.2.

4.2 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 on the ground by mapped vegetation polygons.

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

Control Polygons – areas within vegetation polygons excluded from revegetation treatments (i.e., no revegetation prescriptions will be applied as part of CLBWORKS-1) to serve as statistical controls for the revegetation monitoring (CLBMON-9), and other monitoring programs that are occurring in the drawdown zone of Kinbasket Reservoir (e.g. CLBMON-11A - Wildlife Effectiveness Monitoring of Revegetation in Kinbasket Reservoir). See Section 9.2.2 for selection of control polygons in the drawdown zone of Kinbasket Reservoir.

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 recorded in only one year (for a given landscape unit or vegetation community).

4.3 Design

The study design follows Hawkes et al. (2007), Hawkes and Muir (2008), Hawkes et al. (2010, 2012), and Hawkes and Gibeau (2015, 2017). 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 4.5.3). Locations sampled in 2018 included previously established transects, as well as new transects established to increase the sample size for upper elevation bands. A more detailed account of 2018 (Year 10) follows.

4.3.1 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, 2016, and 2018. 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). 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, 2016, and 2018. In 2018 most aerial photos were acquired between 2 and 6 June when the elevation of Kinbasket Reservoir varied from 734.53 m to 735.78 m ASL (Table 4-1).

Table 4-1: 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. (m ASL)	
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
2018	2-Jun	6-Jun	734.53	735.78

4.3.2 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 2018, with 2016 polygons updated to the 2016 imagery etc.

Because CLBMON-57 addresses the environmental impacts of the installation and operation of Mica Unit 5, the elevation range and associated mapping of the vegetation communities in the drawdown zone of Kinbasket Reservoir was based on the Digital Elevation model (DEM) generated using the 2014 LiDAR data. This differs from the mapping completed for CLBMON-10, which is based on the DEM that was updated in

2010 and based on the contours generated in 2002 from the 1:20,000 black and white aerial (analog) imagery. The LiDAR-generated DEM was used for CLMBON-57 because of the increased precision of the LiDAR data and the associated estimated increase (60 cm) of reservoir elevations associated with the installation and operation of Mica Units. It is unlikely that this this difference would have been detectable using the 2010 DEM.

4.3.3 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 4-2). In 2014 two additional communities (not included in Table 4-2 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 non-forested ecosystem classification described in the *Wetlands of BC* (Mackenzie and Moran 2004). As such, novel community names were derived.

Table 4-2: **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*	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)

4.3.3.1 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 4-3). 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 4-3: **Proposed successional status of 15 of the 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 hawksbeard	Maturing Climax
MC	Mixed conifer	Maturing Climax

4.3.4 Botanical Nomenclature

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.

[4] The concept of climax is a theoretical state and not 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 assumption that the vegetation in those communities is best adapted to the current environment.

4.4 Year 12 – 2018 (Implementation Year 7)

4.4.1 2018 Sampling Objectives

The objectives of the 2018 field sampling were to resample transects established in previous years in the upper elevation band of the drawdown zone (i.e., 752 to 754 m ASL); and to conduct supplemental sampling of this elevation band to obtain additional data on vegetation growing at these elevations. Transect sampling was used to verify whether vegetation communities have changed over time. Transect data were also used to verify the delineation of vegetation community polygons on the aerial photos obtained in 2018. These data were used in conjunction with prior years' data to model the effects of the operation of Mica Unit 5 on existing vegetation in the upper elevation bands.

4.4.2 Field Sampling: Timing and Location

Field sessions were timed to correspond with sampling in previous years (Table 4-4) 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-10/57 while Figure 4-2 provides a summary of the range of reservoir operations in Kinbasket between 1976 and 2018.

Table 4-4: 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. (m ASL)		Field Work 2		Res. Elev. (m ASL)	
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
2018	18-Jun	28-Jun	739.08	743.10	07-Jul	17-Jul	745.08	746.14

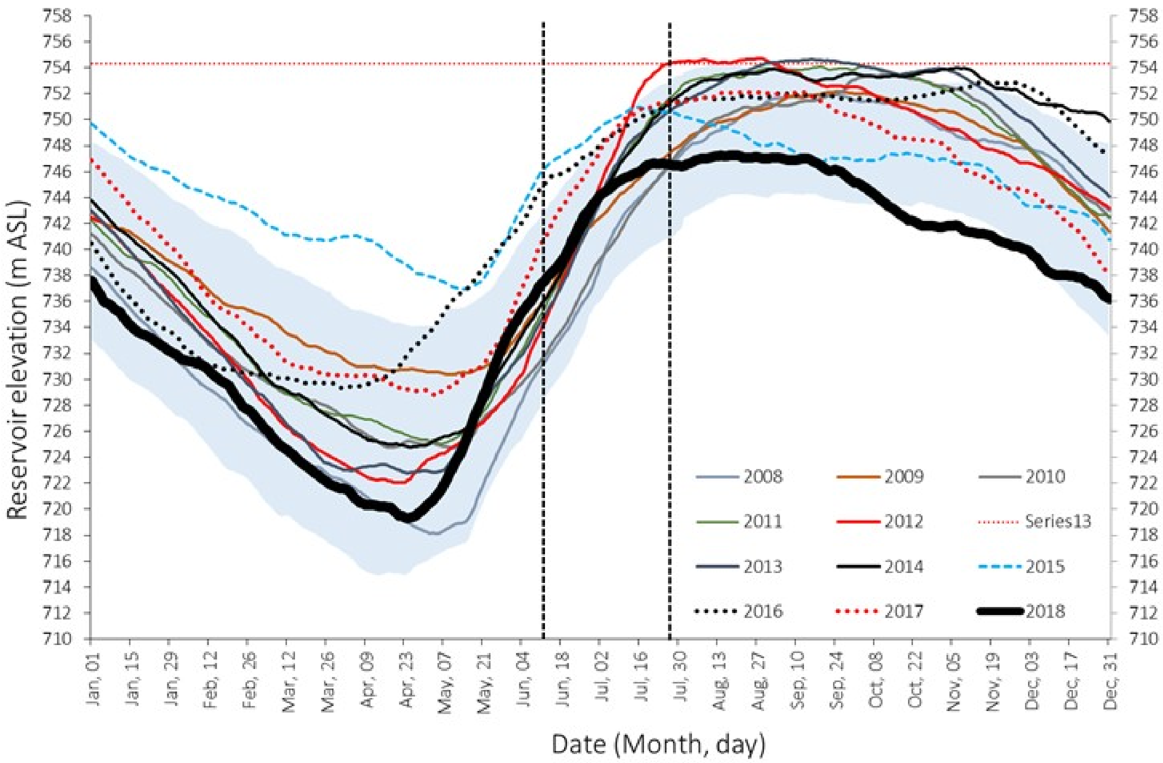


Figure 4-1: Kinbasket Reservoir elevations (m ASL) in 2007, 2008, 2010, 2012, 2014, 2016 and to October 10, 2018. The shaded area indicates the 10th and 90th percentile (1976 to 2018). The 754 m and 741 m ASL elevations are indicated (red dashed horizontal line). Vertical black dashed lines represented the min and max date of sampling (all years).

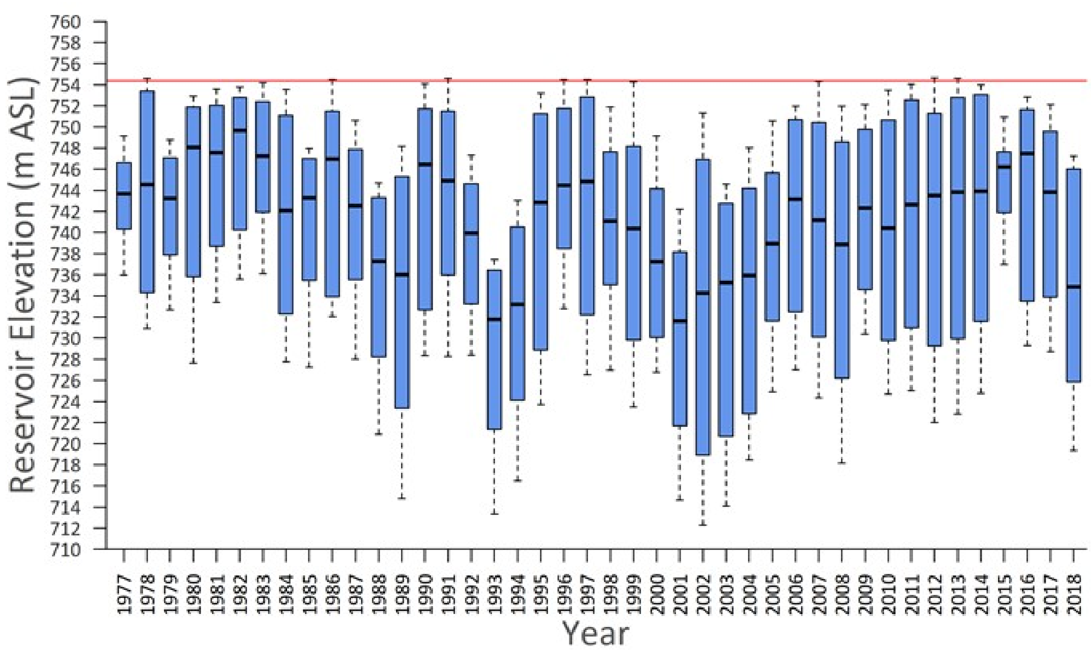


Figure 4-2: Annual variation in Kinbasket Reservoir elevations between 1976 and 2018. The normal maximum of 754.38 m ASL is shown by the horizontal red line.

Sampling locations were predetermined in the office using GIS and were selected to ensure that all landscape units and high-elevation vegetation communities sampled in previous years were resampled in 2018. We began with a selection of 174 transects representing all 21 of the vegetation communities defined for the drawdown zone of Kinbasket Reservoir, including one to two transects each for the previously unmonitored DI (Disturbed) and SW (Shrub-Willow; Section 4.3.3). Of the 174 initial transects, 167 were field-sampled in 2018. All 21 vegetation communities were sampled. Transect locations included all previously mapped landscape units (Figure 3-1).

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. In some instances, the rebar stakes were knocked over or buried under sediment and could not be relocated, in which case UTM coordinates (recorded during establishment) were used.

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.

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

4.5 Variables, Analysis, and Modeling Approach

Most variables (e.g., per cent cover, growing degree days) and statistical methods (e.g., box plots, GLMMs) follow those in Hawkes and Gibeau (2015, 2017). New methods and modeling approaches applied in 2018 are summarized below.

4.5.1 Cover, Richness, and Diversity

Per cent cover, richness, and diversity of plant species was computed and processed for Kinbasket drawdown zone sites as in previous years except that trends were based on six years of data (i.e., 2007, 2010, 2012, 2014, 2016, and 2018); data from 2008 were excluded from analyses for reasons explained in the 2010 annual report (Hawkes *et al.* 2010). However, for 2018, transect data from earlier years (2007 to 2016) were sub-setted so as to retain only data collected at elevations of 752 to 754 m ASL, consistent with the 2018 samples.

4.5.2 Forecasting Models (Mica 5 Predicted Impacts)

To evaluate potential impacts to vegetation from operation of Mica 5, we used field data gathered from 2007 to 2018 to build forecasting models that predicted cover and abundance of vegetation based on site characteristics and reservoir elevations. The primary vegetation variables modeled in 2018 were:

- Herb layer cover (all herbaceous species combined)
- Shrub layer cover (all shrubby species combined)
- Cover of *Carex* (sedge) species
- Cover of *Salix* (willow) species

We then used the forecasting models to simulate what would happen to these plant groups if the reservoir elevation were to be increased by 60 cm in 3 of every 10 years. To allow for variations in inundation timing, we developed three hypothetical schedules for reservoir elevation increase that we then compared against the baseline data. We considered the baseline to be the conditions observed in the Kinbasket Reservoir from 2007 to 2018, acknowledging that these occurred after the reservoir had already been regulated for decades.

1) Development of the forecasting models, in more detail, was as follows:
    a. We included 2007-2018 transect data corresponding to three elevation bands: 752, 753, and 754 m ASL. We used a 0.25-m cut-off to assign a transect to a given elevation band (e.g., 751.75-752.75 m were the limits used for the 752 m band, etc.). Elevations were determined from the 2014 Digital Elevation Model (DEM).
    b. We stratified vegetation cover by herb and shrub layer. We included transects where herb or shrubs appeared or disappeared over time but not transects that contained no herbs or shrubs at all in any year.
    c. For each 20-m belt transect, we computed the average cover per vegetation layer (by averaging over the 10 individual 1-m^2 quadrats in each transect), as well as average covers of *Carex* species and *Salix* species. As an alternative estimate of abundance, the frequency of occurrence of *Carex* and *Salix* in each transect was also computed. Frequency was calculated as the number of times (over 10 quadrats) that a species of *Carex* or *Salix* was recorded in a given transect per year. Thus, we developed a total of six different forecasting models.
    d. We computed monthly growing degree days (GDD) and reservoir variables (depth, duration, and timing of inundation) for each year (2007 to 2018). GDD were computed based on a “30-cm per 7-day rule”. That is, daily GDD were added to the monthly totals for those periods that the elevation band was not inundated by >30 cm of water for >7 days.
    e. We developed generalized linear mixed models (GLMM; Zuur *et al.* 2009) for each of the six dependent variables with transects as random effects to account for repeated measures. Explanatory variables were: slope, heat load (McCune and Keon 2002), GDD from April to September, depth, and duration of inundation. We did not include timing of inundation because of its high collinearity with other explanatory variables. We included a one-year lag on operational variables and GDD from July to September to account for the delayed effects of reservoir levels on vegetation (because sampling occurred in June or July of each year, it always reflected the pre-inundation conditions for that year). GDD from April to June (i.e., pre-inundation ambient conditions) were modeled without a lag. We transformed covers with logit transformation to account for the proportional nature of the data (Warton and Hui 2011) and log-transformed the frequencies of *Carex* and *Salix* (running these two models with a Poisson distribution resulted in a much poorer fit). We standardized all explanatory variables given they were on different dimensions (Legendre and Legendre 2012). We used model selection to look for the best model for

forecasting purposes but kept full models to maximize the amount of variation explained.

2) We then created simulations as follows:
   a. We computed GDD (April to September, based on the 30-cm per 7-day rule) and inundation variables (duration, timing, depth) for all years from 1995 to 2018.
   b. **Baseline.** We randomly selected one year of reservoir variables and GDD and predicted cover or frequency using each of the six models developed in (1) for all transects sampled (*n*=93). We repeated this step 1000 times to derive a distribution of covers and frequencies for the baseline.
   c. We simulated three scenarios:
      i. **Scenario 1**. We added 60 cm to the reservoir elevation each day from April 1 to September 30, for the period 1995-2018. We recomputed GDD and reservoir variables based on these adjusted water levels. We randomly selected one year of reservoir variables and GDD and again predicted cover or frequency using each of the six models developed in #1, ensuring that the +60 cm water years would be selected with a probability of 30% while the "regular" water years—those used in the baseline simulations in (2.b)—were selected with a probability of 70%. We repeated this step 1000 times.
      ii. **Scenario 2**. We repeated the steps in (2.c) for Scenario 1 except that we simulated higher (+60 cm) reservoir elevations only for August of each year. August was used as this was the month when GDD varied most among years.
      iii. **Scenario 3**. We repeated the same steps as for Scenario 1, except that reservoir elevations were increased only for those years that the reservoir exceeded 754 m ASL (i.e., high-water years). This corresponded to 1996, 1997, 1999, 2007, 2011, 2012, 2013, and 2014. We capped the maximum water elevations at 754.38 m ASL to avoid exceeding full pool. High-water years were selected with a 30% probability, while all other years from 1995-2018 were selected with 70% probability. This was expected to be the most "extreme" scenario, as the 30% chance of picking a +60 cm year was concentrated on years that were already characterized by high-water conditions.

Simulation results for the baseline and three +60 cm scenarios were compared using boxplots (Massart et al. 2005). All modelling and simulations were run in the R language (version 3.5.1).

4.5.3 Polygon Data

The analysis of polygon data followed the same approach as in prior years (Hawkes and Gibeau 2015, 2017), except that six years of data (up to 2018) were included. As in 2016 (Hawkes and Gibeau 2017), we used 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 carried out as described in Hawkes and

Gibeau (2017). At the time of this report Kappa statistics for assessing VCC turnover rates at the landscape scale were not yet available.

5.0 RESULTS

5.1 Transects

Since 2007, 220 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 2018, a total of 167 transects were sampled, several of them for the first time. The number of years in which a given transect was sampled ranges from one to six. Overall, seven transects were sampled six times (i.e., in all years excluding 2008), 54 transects were sampled in five of six years, 33 in four of six, four in three of six, six in two of six, and 117 transects were sampled in one year only (including 55 new transects established in 2018).

5.1.1 Community Composition Over Time

The vegetation community types identified in Table 4-2 have remained relatively stable over time, with little change in the dominant species composition of each community (i.e., the same common species continue to define each community; Kendall's coefficient of concordance, $W = 0.152$, $F = 14.5$, $p < 0.0001$). Kendall's Concordance analysis produced two distinct species groupings (Table 9-1) that appear, in a Principal Components Analysis diagram, to correspond to mid/late and early seral communities, respectively (Figure 5-1).

Communities partition along a gradient that is more related to successional status than to year, with early pioneering communities (e.g., LL, TP, CH) clustering together over time relative to mid and late seral communities (e.g., CT, BR SH, and WS; Figure 5-1; Table 9-1). 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 the PCA ordination diagram (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.

5.1.2 Species Constancy

Since 2007, > 300 plant species have been recorded in repeat transects (Appendix: Figure 9-1), including 232 herb and 47 woody species. Most species recorded in a given year were restricted to a single vegetation community, although some species were generalists and observed in two or more VCCs. Common Horsetail (*Equisetum arvense*) and Lakeshore Sedge (*Carex lenticularis*) were two species that appeared in almost all VCCs in each year. Bluejoint Reedgrass (Calamagrostis canadensis), Norwegian Cinquefoil (*Potentialla norvegica*), White clover (*Trifolium repens*), Reed Canarygrass (*Phalaris arundinacea*), and Lady's-thumb (*Persicaria maculata*) were other frequently encountered species.

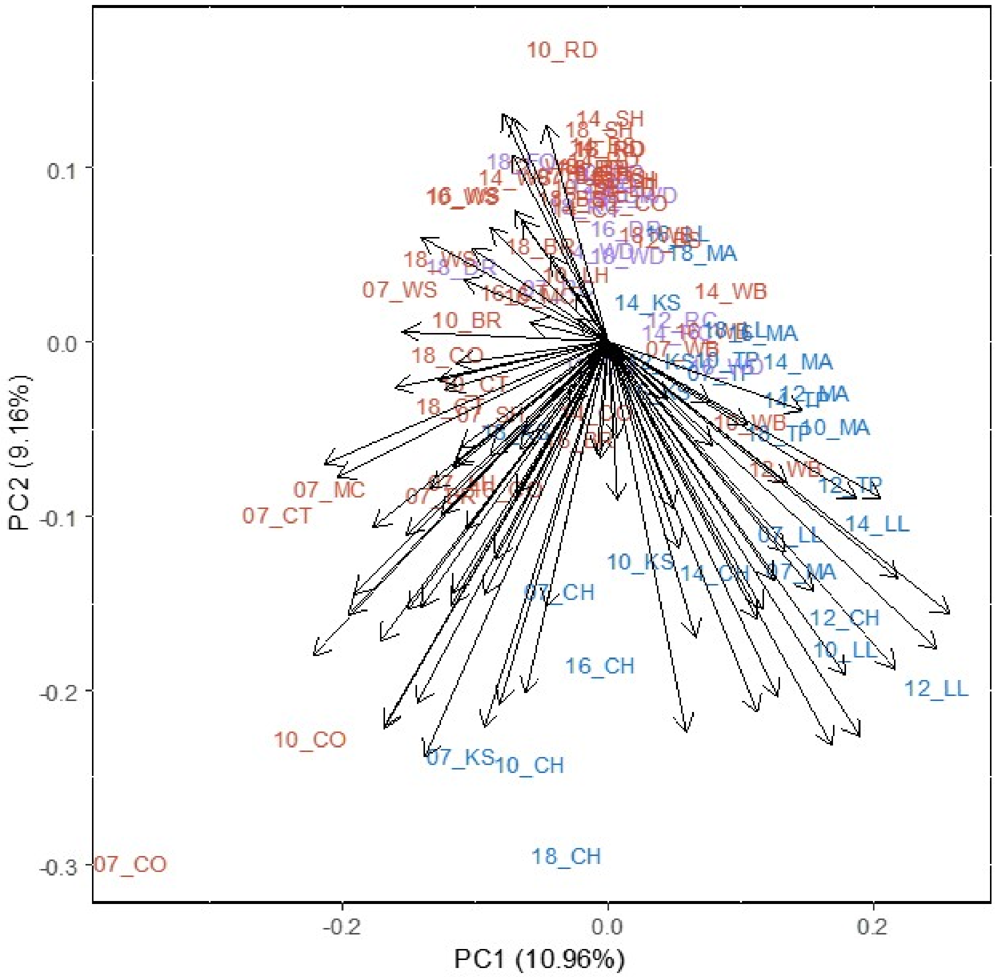


Figure 5-1: PCA ordination diagram with superposition of the results of Kendall Concordance analysis. Black vectors represent species average covers. Species represented are ones that were significantly concordant ($p < 0.05$) based on Kendall's coefficient of correspondence (W). Kendall's Concordance analysis. Axis X expresses 10.96 per cent of the variation of the data set, and axis Y, 9.16 per cent. Community codes are expanded in Table 4-2.

A total of 149 herb species were recorded in 2007, 149 in 2010, 82 in 2012, 102 in 2014, 130 in 2016, and 154 in 2018 (excluding transects newly established in 2018). Of these, 66 species were recorded in one year only, 39 were recorded in two years, 22 were recorded in three years, 22 were recorded in four years, 30 were recorded in 5 years, and 53 were recorded in all six years (excluding 2008). Differences in total numbers of plants per year can be partly attributed, on the one hand, to the high reservoir elevations in 2012 and 2014 that limited sampling at lower elevations. On the other hand, the high species tally for 2018 may be reflective of a directional increase in species establishments at higher elevations after the sequence of relatively low water years that has prevailed since 2015.

Herb species constancy per transect (the proportion of all species recorded in 2018 that also appeared in a prior year) for a given community ranged from 33 (for DR [Driftwood] to 100 per cent (for one transect containing just a single species in the LH [Lodgepole pine - Annual hawks beard]; Table 9-2).

Constancy averaged 82 per cent over all community types, with CH (Common horsetail), MA (Marsh cudweed – Annual hairgrass), KS (Kellogg's sedge), BR (Bluejoint reedgrass), and WB (Woolgrass – Pennsylvania buttercup) registering constancies of ≥ 90 per cent and TP (Toad rush – Pond water-starwort) and CT (Cottonwood – Clover) registering constancies of < 75 per cent. KS (Kellogg's sedge) had the highest number (14) of species recorded in all six years of sampling, while the high elevation Driftwood (DR) VCC had the largest number of novel species records in 2018 (14; Table 9-2).

For shrub and tree species, constancy ranged from 20 (DR) to 100 per cent (BR and WS (Willow – Sedge wetland), averaging 80 per cent over the various VCCs (Table 9-2). Shrubs and trees were recorded at least once in 14 VCCs; however, in 2018 most woody species diversity was concentrated in CO, WS, CT, and DR.

The number of unique species (those recorded in just a single year) was relatively consistent from 2010–2016, with between 3 and 21 unique species per year. However, a higher number of unique species (17) was documented in 2018 (Table 9-2). This 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 three preceding years—allowing for increased in-growth of vegetation, particularly at higher elevations (i.e., those > 751 m ASL). Among community types, the highest occurrence of unique herbs in 2018 (after correcting for the number of transects sampled each year) was associated with the DR community followed by the TP and the WS communities (Figure 5-2). The most variable community over time (i.e., exhibiting a high incidence of short-term species occupancy) tended to be the MA, BS (Buckbean – Slender sedge), WS (Willow – sedge wetland), CT, LH, and DR; low elevation and wetland communities including CH, KS, WB, and SH (Swamp horsetail) tended to be the least labile from year to year (with relatively low rates of species turnover; Figure 5-2). The variability of WS, CT, LH, and DR may reflect their 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.

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 Canoe Reach (CNR), Bush Arm (BSA), and Encampment Creek (Enc; Figure 9-3, top). LSUs with low numbers of unique species included MB (Mount Blackman) and Bea (Beavermouth). Most of the new species recorded in 2018 were in Bear Island (BIS), Bush Arm, Encampment Creek, and Canoe Reach; Figure 9-3, bottom).

5.1.3 Vegetation Communities and Elevation

The distribution of vegetation communities relative to elevation in the drawdown zone of Kinbasket Reservoir in 2007-2018 study years is shown in Figure 5-2. As previously reported (Hawkes and Gibeau 2017), the range of elevations across which VCCs occur has been fairly consistent between years. However, there has been an increase in mean elevation for Clover-Oxeye daisy (CO), Driftwood (DR), Common horsetail (CH), Unclassified forest (FO), Swamp horsetail association (SH), and Wood debris 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 5-2). Both TP and DR showed a significant change in elevation distribution; 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) 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.

5.1.4 Species Richness and Diversity

Species richness per transect (computed as the total number of species recorded divided by the number of transects sampled) varied among VCCs and over time (Figure 9-4). High herb richness was generally associated with Buckbean-Slender sedge (BS) and Willow–Sedge wetland (WS), although other VCCs such as Marsh Cudweed—Annual Hairgrass (MA), Wool-grass—Pennsylvania buttercup (WB), and Cottonwood–Clover (CT) showed comparably high herb richness values in some years (especially 2007). Consistently low herb richness was associated with early pioneering communities such as Lady's thumb—Lamb's quarter (LL) and Common horsetail (CH). Except for a few vegetation communities, herb richness per transect appeared to be relatively similar across most years (bottom panel, Figure 9-4). Notable outliers include WB and CT communities in 2007, MA in 2007 and 2016, and WS in 2012. Herb richness per transect of various VCCs in 2018 was generally comparable to that of prior years, although richness was notably lower relative to 2016 in the LL, MA, and Lodgepole pine–Annual hawksbeard (LH) VCCs (Figure 9-4).

As of 2018, richness per transect of woody species, while generally low, was highest in the WS, CT, and Canary Reedgrass (RC) VCCs (top panel, Figure 9-4).

The most speciose transects tended to be associated with the Toad rush–Pond water-starwort (TP), Marsh cudweed–Annual hairgrass (MA), Kellogg's Sedge (KS), Woolgrass–Pennsylvania buttercup (WB), Buckbean–Slender sedge (BS), and Willow–Sedge wetland (WS). The Common horsetail (CH), Swamp horsetail (SH), and Driftwood (DR) tended to occupy the lower end of the richness spectrum. However, species richness and diversity of individual transects varied among vegetation communities and across time (Figure 5-3). For certain vegetation communities (e.g., CH, Marsh cudweed–Annual hairgrass [MA],Lady's thumb–Lamb's quarter [LL], Bluejoint reedgrass [BR], Woolgrass–Pennsylvania buttercup [WB]), median transect richness appears to have decreased somewhat since 2007 (Figure 5-3, top panel). For most others, however, richness has remained more or less stable over time or has fluctuated from sample year to sample year, exhibiting no apparent trends (e.g., Kellogg's Sedge [KS], Clover–Oxeye daisy [CO]).

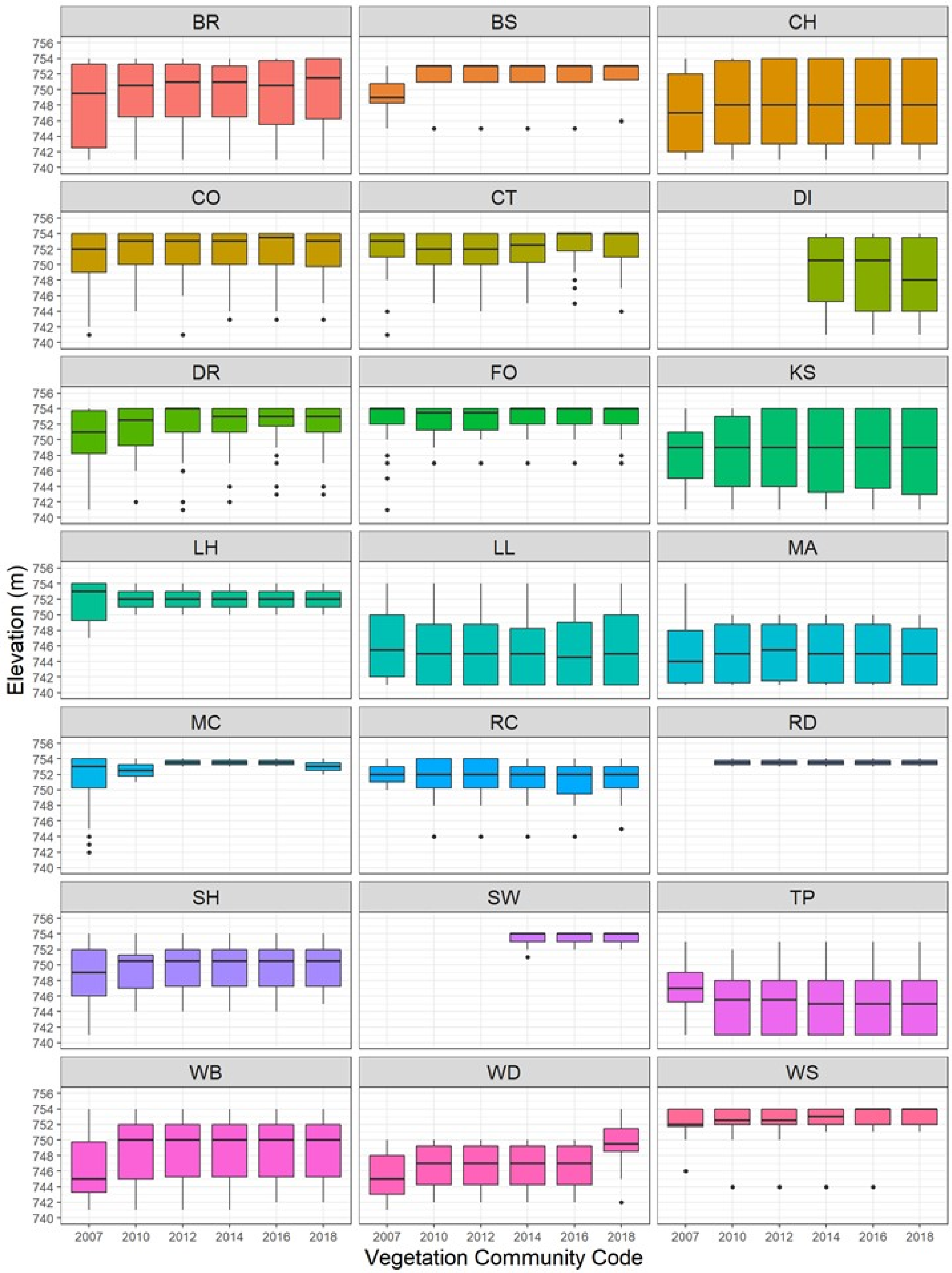


Figure 5-2: Elevation range associated with each of the vegetation communities characterized in the drawdown zone of Kinbasket Reservoir in 2007, 2010, 2012, 2014, 2016, and 2018. Communities codes are expanded in Table 4-2. Disturbed (DI) and Shrub Willow (SW) communities were not considered in analyses.

The most diverse transects, as measured by Shannon's H, tended to be associated with the Lady's thumb–Lamb's quarter (LL), Clover–Oxeye daisy (CO), and Willow–Sedge wetland (WS) VCCs, while Common horsetail (CH) and Driftwood (DR) transects typically showed low diversity (bottom panel, Figure 5-3). However, communities were not strongly differentiated in this regard. Diversity varied among vegetation communities and years (as it did with richness) and for some VCCs (e.g., LL, Marsh cudweed–Annual hairgrass (MA), Bluejoint reedgrass (BR), and Woolgrass–Pennsylvania buttercup [WB]) appeared to undergo a decline in 2018 relative to previous years. Results from a Generalized Linear Mixed Model (GLMM) suggest that variation in both richness and diversity was statistically significant among years ($F = 22.2$, $p < 0.01$, and $F = 27.9$, $p < 0.01$, respectively) and VCCs ($F = 4.9$, $p < 0.01$, and $F = 3.4$, $p < 0.01$, respectively). Interactions between year and VCC were not significant. Because of lack of replicates for some VCCs in one or more years, only the following VCCs were tested: BR, CH, CO, KS, LL, SH, and WB.

Assessing the variation in species richness and diversity over time confirmed several observations made in previous reports (Hawkes and Gibeau 2015). For example, richness and diversity increased with elevation (richness: $t = 3.41$, $p < 0.01$; diversity: 2.02, $p < 0.01$) and decreased over time (i.e., years; richness, $t = -6.14$, $p < 0.01$; diversity, $t = 8.0$, $p < 0.01$; Figure 5-4). Richness is predicted to increase with later onset of inundation (i.e., timing; $t = 3.03$, $p < 0.01$). Richness and diversity also differed between landscape units, in many instances significantly. For example, Sprague Bay, KM 79, and Encampment Creek transects had higher species richness and/or diversity relative to transects at Windfall Creek, Sullivan Arm, Hugh Alan Bay, Grouse Creek, or Deer Creek (Figure 5-4; see also Appendix: Figure 9-5 and Figure 9-6). Note that, because LSUs represent non-quantitative variables, they can be compared to each other (via their overlapping or non-overlapping confidence intervals) but not to 0.

With respect to growing degree days, richness and diversity were predicted to increase with increasing September GDD (richness: $t = 1.88$, $p=0.06$; diversity: $t = 2.38$, $p = 0.02$). That is, richness appeared to be positively correlated with increased exposure and warmth during September (Figure 5-4). This result contrasts slightly with 2016, when both September and August GDD were positively correlated with richness (Hawkes and Gibeau 2017). The effect of reservoir elevations and GDD and associated effects on richness is further supported by the fact that higher elevations are associated with higher species richness and diversity, although there is lower confidence in the result for diversity ($t = 1.58$, $p = 0.12$; see also Figure 9-7). These results underscore the negative effects that reservoir operations, particularly, higher reservoir elevations, can have on the species richness and diversity of vegetation in the drawdown zone of Kinbasket Reservoir.

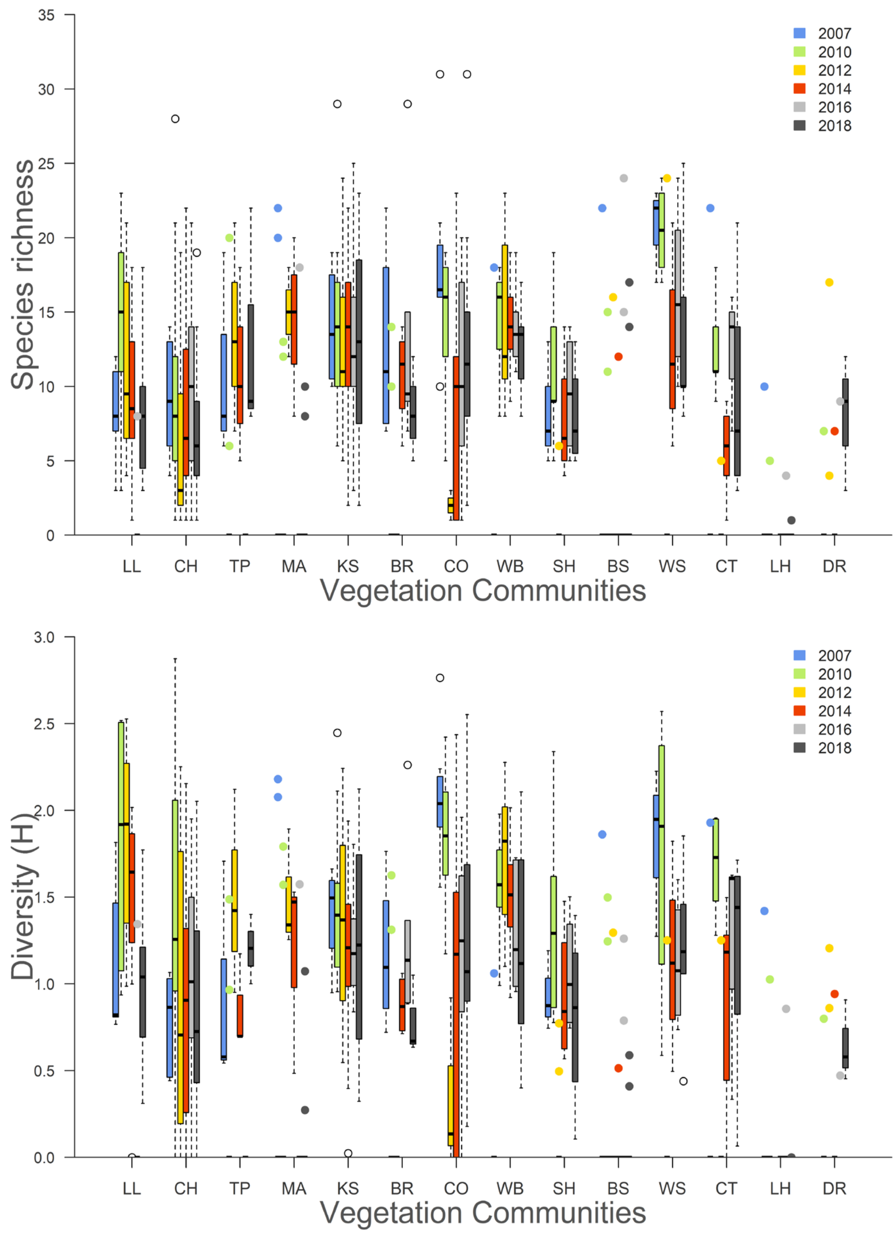


Figure 5-3: **Variation in herb species richness (top) and diversity (Shannon's H; bottom) per transect over time, per vegetation community. VCC-Year combinations with < three data points are displayed by dots only.** Vegetation community codes are expanded in Table 4-2.

5.1.5 Red- and Blue-Listed Plants

Since 2007, we have documented the presence of eight Blue- or Red-listed plants in and adjacent to the drawdown zone of Kinbasket Reservoir. However, as of 2018, all but two of these species had been down-listed to Yellow status (). None of the plants have COSEWIC (Committee on the Status of Endangered Wildlife in Canada) or *SARA* designation, nor are federal status reports being prepared. However, data collected for CLBMON-10 and CLBMON-57 contributed to an increased understanding of the current distribution of these species in BC. For example, one Blue-listed species—Moss grass—was recorded for the first time in Kinbasket Reservoir (KM 79) in 2018. This observation represents a significant range extension for this rare species in British Columbia, the closest other records being Shuswap Lake and Arrow Lakes Reservoir (Miller and Hawkes 2015).

Of the two confirmed Blue-listed species—Moss grass and Yellow widelip orchid—the former is least likely to experience negative impacts related to Mica 5 implementation, since it occurs at mid-elevation in the drawdown zone and appears well adapted to prolonged seasonal inundation (Miller and Hawkes 2015). In contrast, Yellow widelip orchid is restricted to the highest elevation zones at KM 88 and Bush causeway, where it likely experiences inundation only during full-pool events. This species has not been re-recorded following the 2012 and 2013 surcharge events, and its current status in Kinbasket Reservoir is unclear. It is possible that populations have not yet recovered from the effects of this disturbance. For this reason, it is recommended that any post-impact monitoring of Mica 5 impacts should also incorporate additional population monitoring for this species.

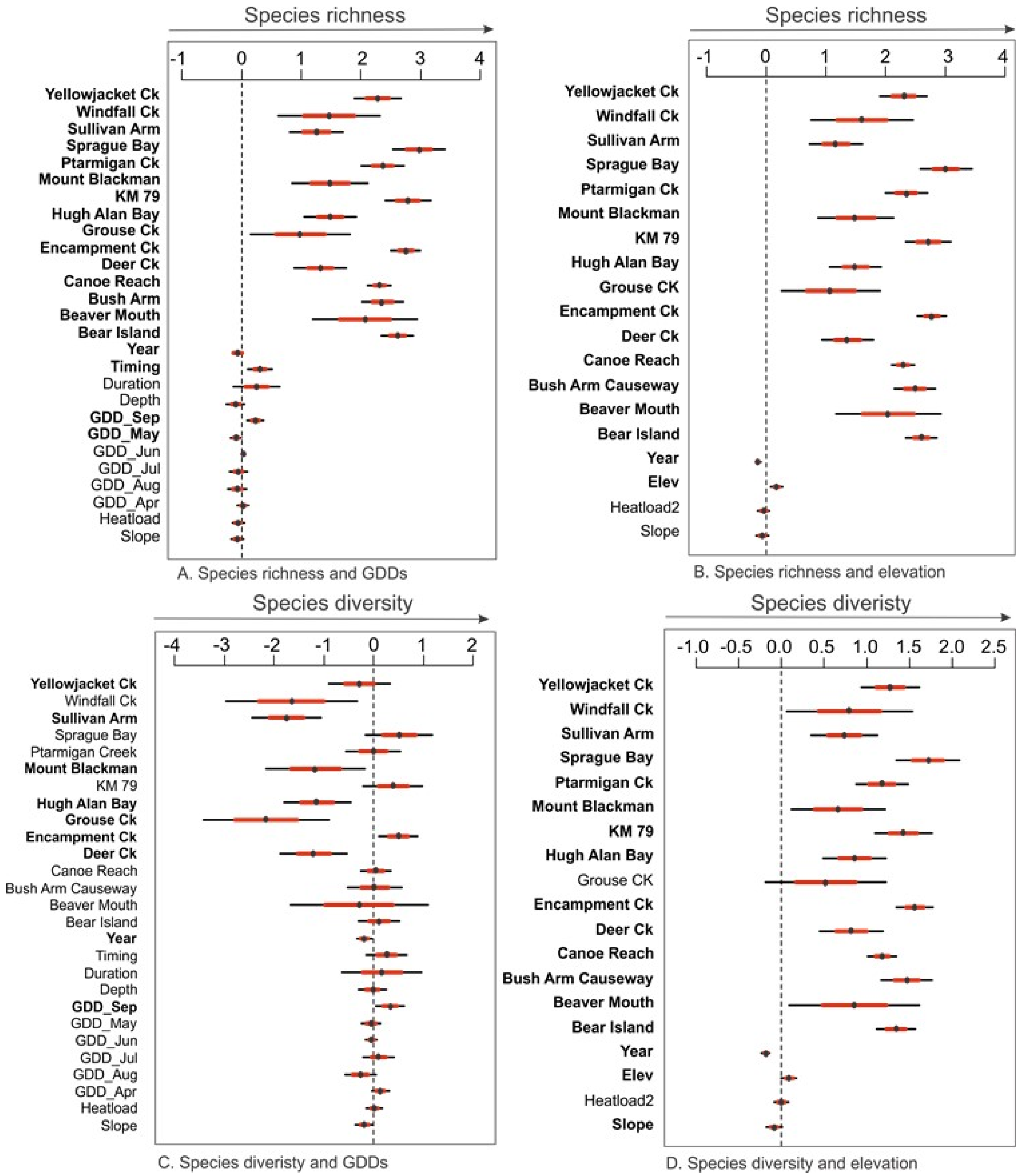


Figure 5-4: **Coefficient plots showing the value of the standardized regression coefficient (black rectangles) ± 2 SE (red line) for each fixed effect included in the GLMM, along with the 95 per cent confidence interval (horizontal black lines) for fixed effects.** Because elevation is correlated with water depth and growing degree days (GDD), the effects of water depth and GDD were modelled separately. Variables with bold text were significant at $\alpha = 0.1$. For quantitative variables, 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. LSUs (non-quantitative

variables) cannot be compared to 0; these differ from each other if their respective error bars do not overlap.

Table 5-1: 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	2018
Carex crawei	Crawe's Sedge	Yellow-listed	Y	Y	N	Y	N	N	N
Carex tonsa	Bald sedge	Yellow-listed	Y	N	N	Y	N	N	N
Coleanthus subtilis	Moss grass	Blue-listed	N	N	N	N	N	N	Y
Eleocharis elliptica	Elliptic spike rush	Yellow-listed	Y	N	Y	Y	Y	Y	N
Liparis loeselii	Yellow widelip orchid	Blue-listed	Y	N	Y	Y	N	N	N
Erythranthe breviflora	Short flowered monkey	Yellow-listed	Y	Y	Y	N	N	N	N
Erythranthe breweri	Brewer's monkey	Yellow-listed	Y	N	Y	Y	N	N	N
Packera plattensis	Plains butterweed	Yellow-listed	Y	Y	Y	Y	N	N	N
Juncus stygius[1]	Bog rush	Yellow-listed	--	--	--	Y	N	N	N
Dryopteris cristata[1]	Crested wood fern	Yellow-listed	--	--	--	Y	N	N	N
Muhlenbergia glomerata[3]	Marsh muhly	Yellow-listed	--	--	--	--	N	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.

5.1.6 Predictive Models (GLMMs)

5.1.6.1 Total Cover of Herbs and Shrubs

For both total herb and total shrub cover in the upper elevation bands (> 752 m ASL), GLMMs showed generally good fit except in the case of very low and very high values (diagnostic plots not shown). For herb cover, GLMMs indicated that up to seven explanatory variables were significant (Figure 5-6; Appendix: Table 9-3).

Herb cover was predicted to decrease with increasing GDD in April ($t = -3.18$, $p<0.01$), July ($t=-4.17$, $p<0.01$), and August ($t=-4.02$, $p<0.01$), and with increasing slope ($t = -3.41$, $p <0.01$) and water depth ($t = -2.18$, $p = 0.03$). Cover was predicted to increase with increasing GDD in June and September ($t = 3.98$, $p < 0.01$). Among GDD months, July had the largest coefficient value based on the Wald tests (Appendix: Table 9-3) and thus the largest relative impact on cover.

Note that, for the elevation band under consideration (752-754 m ASL), April-June GDD reflects the ambient temperatures of the current year, whereas July-September GDD are computed from ambient temperatures plus inundation status at t_{-1} (reflecting a one-year time-lag in inundation effects; see Methods). Therefore, only those GDD effects associated with July or later are likely to be closely related to reservoir operations.

For shrub cover, two explanatory variables were significant; cover was predicted to decrease with increasing duration of inundation ($t= -3.11$, $p < 0.01$) and June GDD ($t = -2.12$, $p = 0.04$) and to increase with increasing slope ($t = 2.10$, $p = 0.04$; Figure 5-6; Appendix: Table 9-3). Among GDD months, as for herb cover, June and July had the largest coefficient values based on the Wald tests (Appendix: Table 9-3) and thus the largest relative impacts on cover.

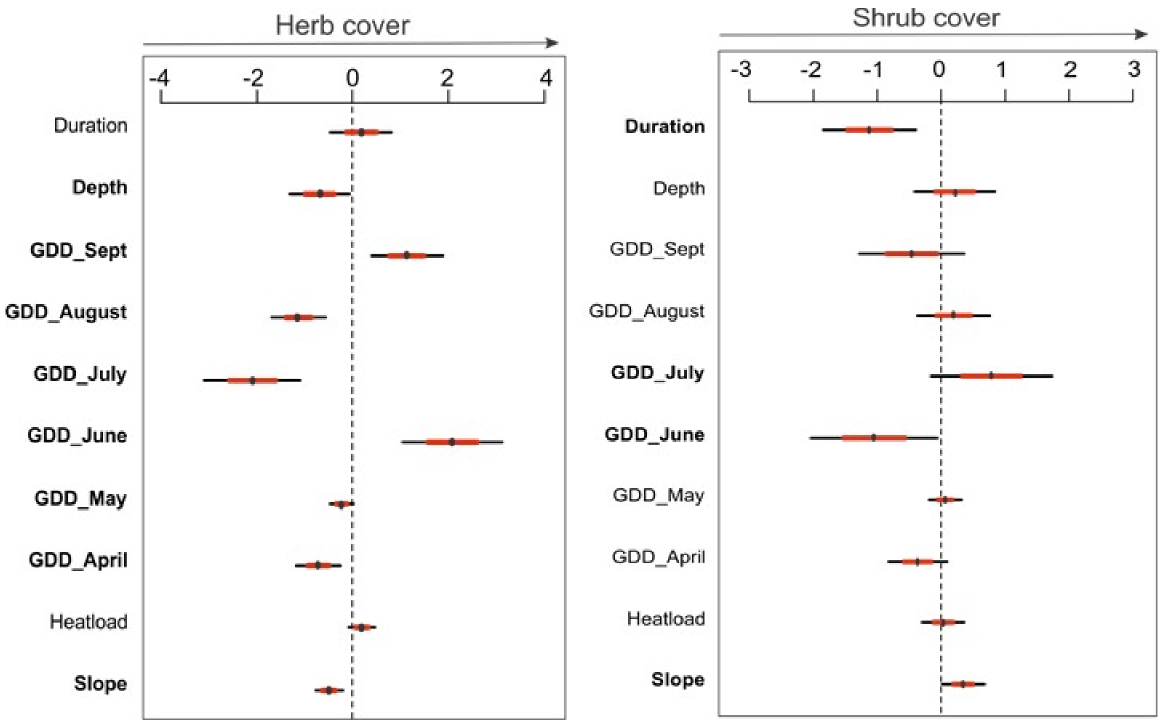


Figure 5-5. **Coefficient plots showing the value of the standardized regression coefficient (black rectangles) ± 2 SE (red line) for each fixed effect included in the GLMM, along with the 95 per cent confidence interval (horizontal black lines) for total herb cover (left) and total shrub cover (right) in the upper (752-754 m ASL) elevation bands of Kinbasket Reservoir drawdown zone.** Variables with bold text were significant at $\alpha = 0.1$. Values < 0 indicate cover was negatively correlated with the modelled explanatory variable while those > 0 indicate increasing cover relative to the variable.

5.1.6.2 Cover and Frequency of *Carex* and *Salix*

None of the modelled factors had a clear directional effect on the cover of sedges (*Carex* spp.) within the upper elevation bands. Cover of willows (*Salix* spp.) was predicted to decrease with inundation duration (t = -1.95, p = 0.06), but other factors were non-significant (Figure 5-6; Appendix: Table 9-3).

Frequency of occurrence of sedges (upper elevation bands) was predicted to decrease with increasing slope (t = -1.76, p = 0.08) and to increase with May growing degree days (t = 2.12, p = 0.04). Frequency of willows was predicted to decrease with increases in four variables: April GDD (t = -1.94, p = 0.06), September GDD (t= -2.62, p = 0.01), depth of inundation (t = -1.96, p = 0.06), and duration of inundation (t = -1.84, p = 0.08; Figure 5-6; Appendix: Table 9-3).

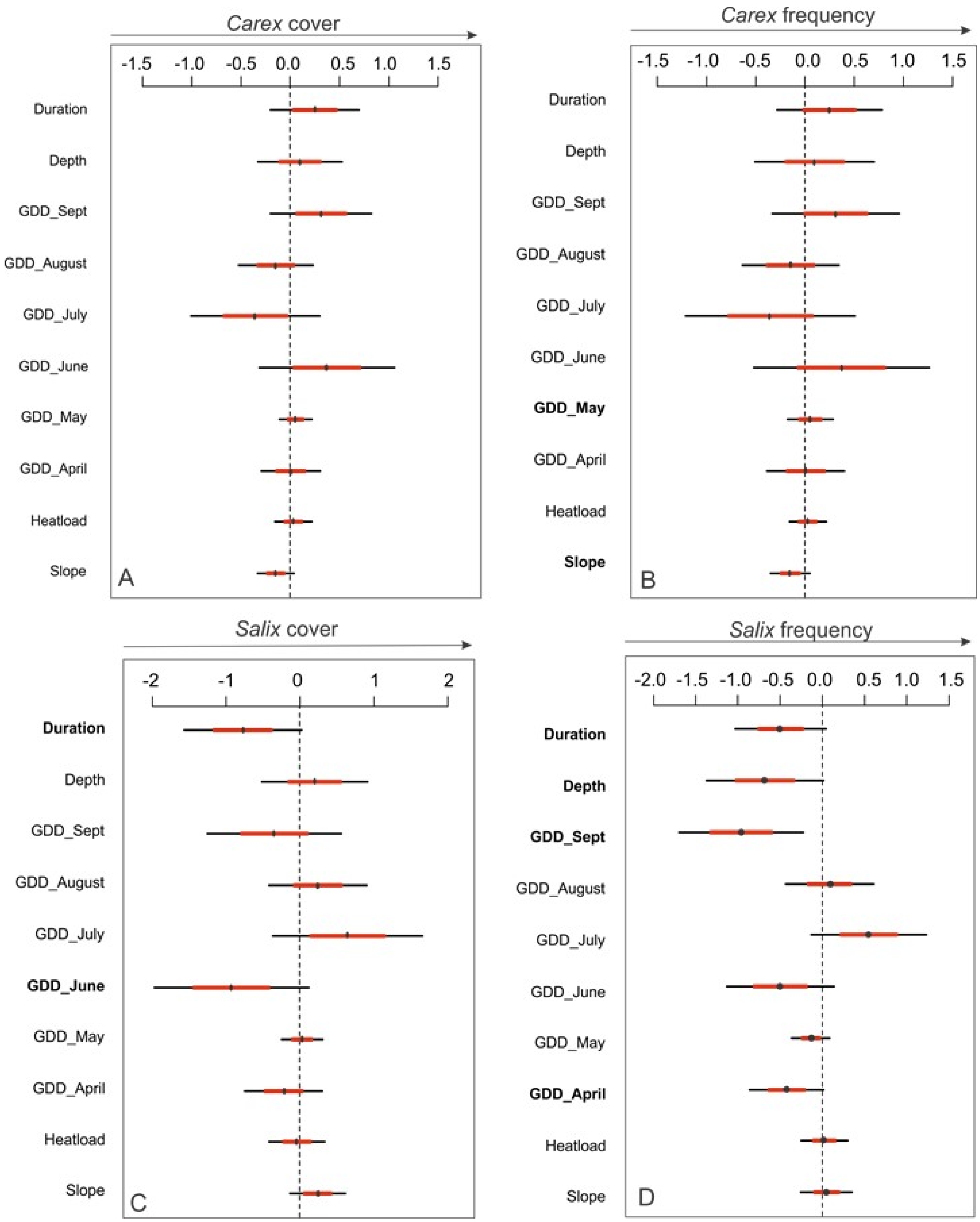


Figure 5-6 **Coefficient plots showing the value of the standardized regression coefficient (black rectangles) ± 2 SE (red line) for each fixed effect included in the GLMM, along with the 95 per cent confidence interval (horizontal black lines) for *Carex* cover (top left), *Carex* frequency (top right), *Salix* cover (bottom left), and *Salix* frequency (bottom right) in the upper (752-754 m ASL) elevation bands of Kinbasket Reservoir drawdown zone.** Variables with bold text were significant at $\alpha = 0.1$. Values < 0 indicate cover was negatively correlated with the modelled explanatory variable while those > 0 indicate increasing cover relative to the variable.

Thus, while inundation variables and growing degree days were associated to a varying degree with changes in vegetation cover and frequency in the upper (752-754 m ASL) elevation bands of Kinbasket Reservoir drawdown zone, few consistent trends emerged from the GLMMs or Wald tests.

5.1.6.3 Simulation Models (Mica 5 Impacts)

Simulation models did not detect any substantial effects on total herb or total shrub cover from increasing reservoir elevations by 60 cm in 3 out of 10 years, for any of the three different inundation scenarios simulated (Figure 5-7). Simulations yielded similarly neutral results in the case of *Carex* spp. and *Salix* spp. per cent covers (Appendix: Figure 9-8) and frequencies of occurrence (Appendix: Figure 9-8).

In the case of total herb cover, there was a weak trend toward decreased median cover for all scenarios compared to the baseline, and a weak trend toward increased median cover in the case of shrubs (Figure 5-7); however, the differences were non-significant relative to the overall variation of the projections. Acknowledging that the available data set is limited in terms of size and scope, it appears that any potential vegetation impacts associated with a semi-periodic increase in reservoir levels by 60 cm are likely to be swamped by the environmental noise of much larger inter-annual fluctuations in inundation depth and duration.

5.2 *Landscape* Polygons

5.2.1 Spatial Extent of Vegetation Communities

Since 2007, the total spatial extent of mapped vegetation (all LSUs combined) in the drawdown zone of Kinbasket Reservoir has increased by ~ 9 per cent (2018 vs. 2007; ~ 178 ha), although some individual LSUs have experienced a decreasing trend over that time (Figure 5-8; Appendix: Table 9-4). Since 2010, vegetation extent has largely either stabilized or increased (Figure 5-8; Appendix: Table 9-4). The variation within each LSU can be characterized as either: 1) stabilizing following a decrease after 2007 (n = 3; e.g., Beavermouth); 2) increasing over time (n = 4; e.g., Canoe Reach); or 3) fluctuating with minor changes (n = 9; e.g., Encampment Creek). The reduction in the extent of vegetation following 2007 is explained in part by mapping refinements introduced in 2010, in part by the dying off of woody 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. Other possible explanations for the reduction in vegetation cover in 2007 include unmeasured (but observed) erosion and sedimentation, which may have removed or covered vegetation.

The total spatial extents of the mapped VCCs also varied over time (Figure 5-9; Appendix Table 9-5). Over the monitoring period, VCCs could be generally characterised as either: 1) stable over time (n = 2; MA and KS); 2) increasing then stable (n = 7; e.g., TP); 3) decreasing then stable (n = 7; e.g., CH); or 4) fluctuating (n = 5; e.g., RC; Figure 5-9; Appendix: Table 9-5). Since 2010, six VCCs have increased by 10 per cent or more (MA, WB, WS, CT, DR, and FO), seven have decreased by 10 per cent or more (BR, RC, RD, CO, SH, MC, and WD), and six have not changed (LL, CH, MA, KS, BS, and LH).

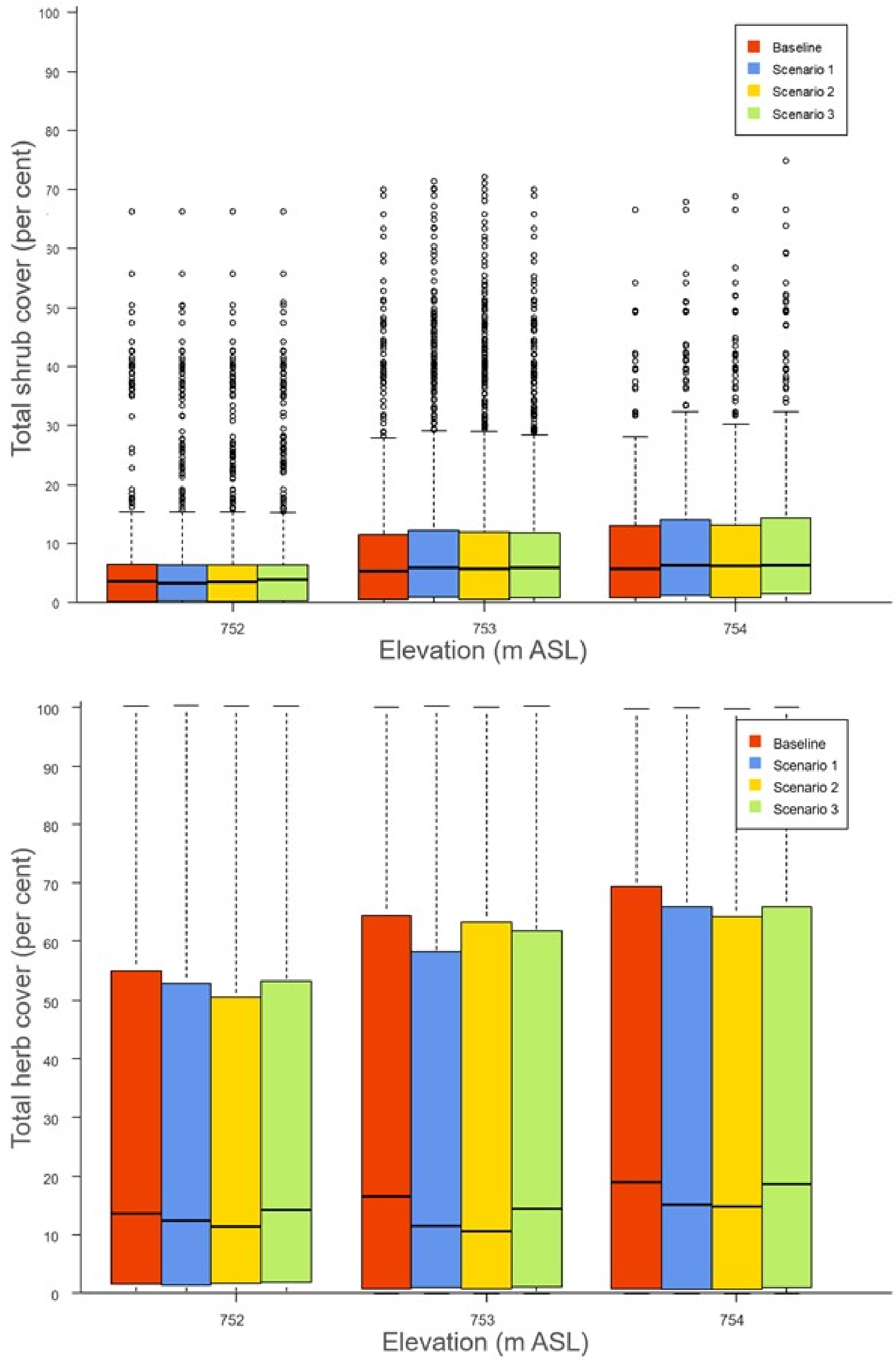


Figure 5-7. **Variation in predicted total per cent herb cover (bottom panel) and shrub cover (top panel) under baseline conditions and three scenarios of increased (+60 cm) reservoir elevations over 1000 simulations per elevation band.** See Methods for scenario descriptions.

Appendix: Figure 9-10 shows the variation in size among polygons demarcating each separate VCC occurrence. Large polygons were mapped mostly for early pioneering vegetation communities (i.e., LL, TP, and KS), with some polygons reaching over 250 ha. However, most polygons were much smaller than 50 ha (average=3.7 ha, SD=4.3 ha, median=1.4 ha). Notably, the WD VCC had larger polygons than other high-elevation communities and showed the most variability by far among years—consistent with the mobile nature of this community type (Appendix: Figure 9-10).

The relative size distribution of vegetation communities by landscape unit and year indicates how each community type contributed to the total vegetation cover each year (Figure 5-11). 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 among the most diverse landscape units, consistent with the greater spatial extent of mapped vegetation communities within these units.

As in 2016, the vegetation community with the largest spatial extent in 2018 were the pioneering LL and CH communities in Bush Arm and Canoe Reach; as was the case in 2007 (Figure 5-11). 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 three landscape units: Bush Arm, Bear Island, 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. Most landscape units supported much smaller spatial extents of VCCs than Bush Arm, Bear Island, and Canoe Reach. KM 79 and Succour Creek were the reaches with the next most extensive communities. WD was only mapped in Canoe Reach, and its spatial extent decreased substantially since 2007 (Table 9-5; Figure 5-11).

The spatial extent of mapped vegetation was maximal at an elevation of 745 m ASL in Kinbasket Reservoir in 2018, with ~ 180 ha, and lowest at an elevation of 754 m ASL, with ~ 110 ha (Appendix: Figure 9-11). This contrasts slightly with 2016, when spatial extent peaked at 743 m ASL at ~ 195 ha. Spatial extents of the top elevation bands (752-754 m ASL) also declined slightly relative to 2016 (Gibeau and Hawkes 2017). The number of VCCs mapped peaked (n = 20) at an elevation of 752 m ASL. Elevations below 744 m had fewer than 12 VCCs, and the lowest elevation (741 m) had only eight VCCs (Appendix: Figure 9-11).

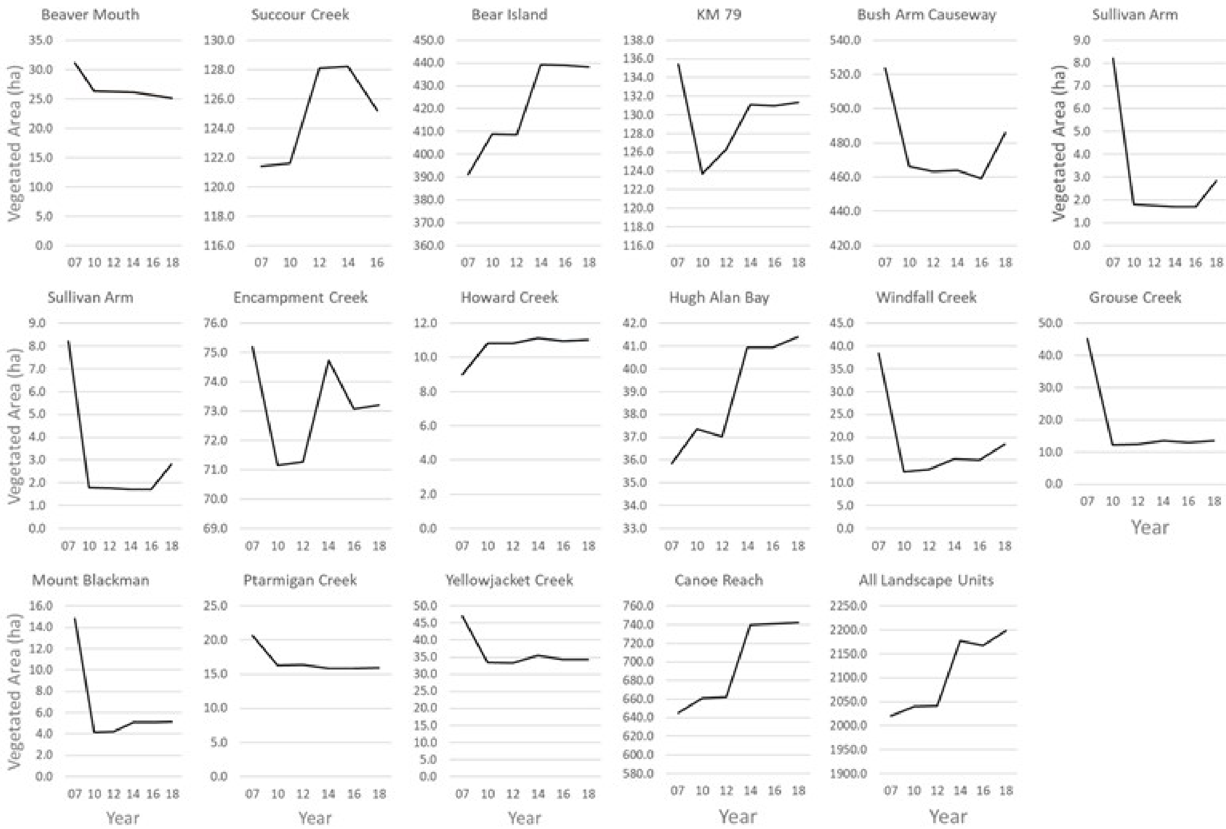


Figure 5-8: The extent of vegetation mapped in each landscape unit and overall between 2007 and 2018. Landscape units are ordered from south (top left panel) to north (bottom right panel; Canoe Reach). The extent of vegetation mapped for all landscape units combined is provided in the bottom right panel. Note varying scales on the y-axis of each panel. Note that y-axis values differ by landscape unit.

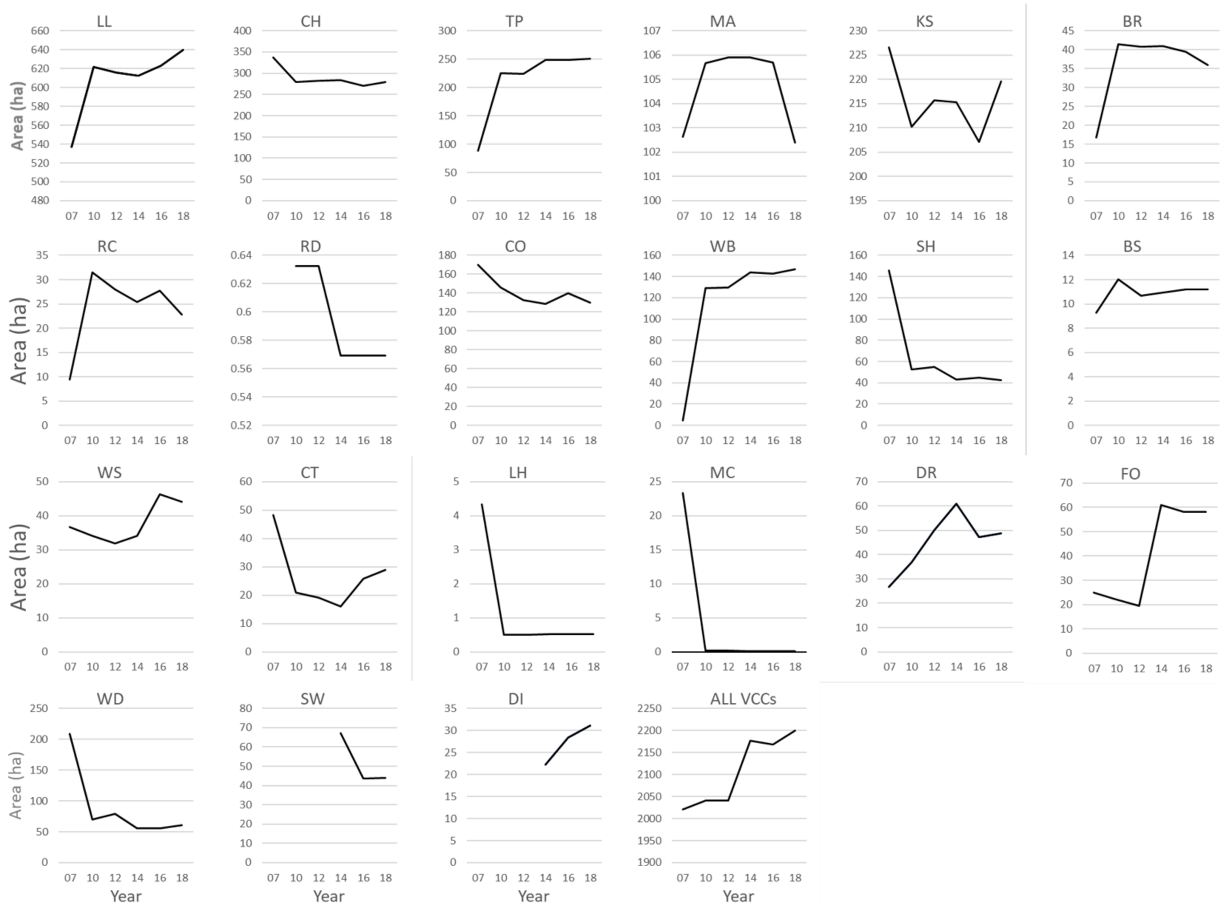


Figure 5-9: The extent of vegetation mapped for each vegetation community between 2007 and 2018. Vegetation communities are ordered from early pioneering to late seral stages in Kinbasket Reservoir. Note that y-axis values differ by vegetation community.

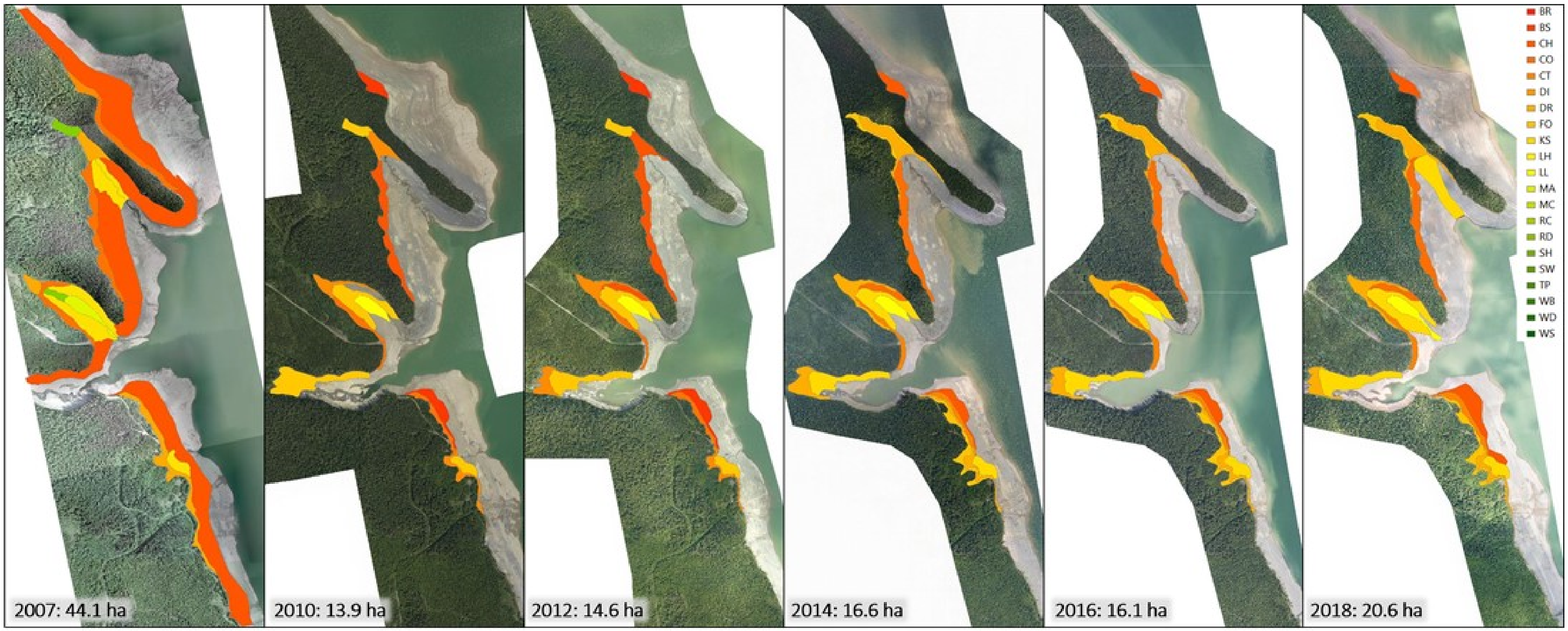


Figure 5-10: Example of changes in the spatial extent of mapped vegetation at Windfall Creek, 2007 to 2016. The reduction following 2007 was related to refined mapping methods and the acquisition of field data (see Hawkes *et al.* 2010). The variation in spatial extent from 2010 to 2016 was minimal. Vegetation community codes are expanded in Table 4-2.

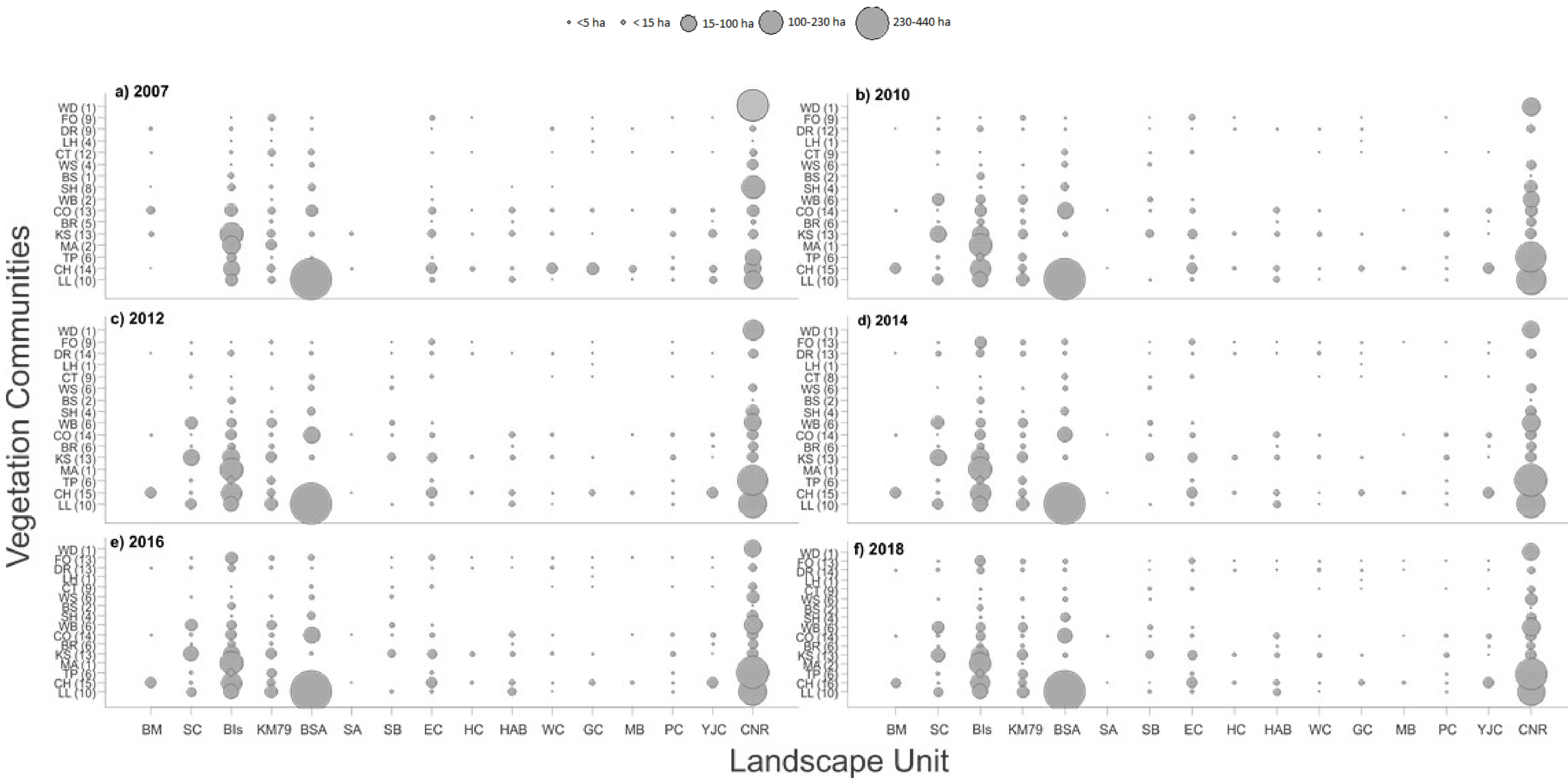


Figure 5-11: The relative size distribution of each vegetation community by year and landscape uni. Vegetation community codes are expanded in Table 4-2 The size of the points is proportional to the communities' spatial extent in the landscape unit over time. The number in brackets after the vegetation 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; SC = Succour Creek; BIs = Bear Island; KM79= KM 79; BSA = Bush Arm; 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.

Variation in spatial extent in response to factors such as vegetation community, year, growing degree days (GDD), and water depth is illustrated in Figure 5-12. Two VCCs (TP and CH) showed a significant increase in spatial extent compared to the CO community, whereas five (WD, SH, LH, FO, and DR) showed a significant decrease in spatial extent compared to CO (Figure 5-12). Taking all factors into account, the spatial extent of VCCs in general was positively correlated with inundation duration ($t = 2.37$, $p = 0.02$) but decreased significantly with water depth ($t = -7.87$, $p < 0.0001$). Spatial extent increased with GDD in May ($t = 3.61$, $p < 0.01$) and August ($t = 1.86$; $p=0.06$) and decreased with increasing GDD in September ($t = -2.02$, $p = 0.04$).

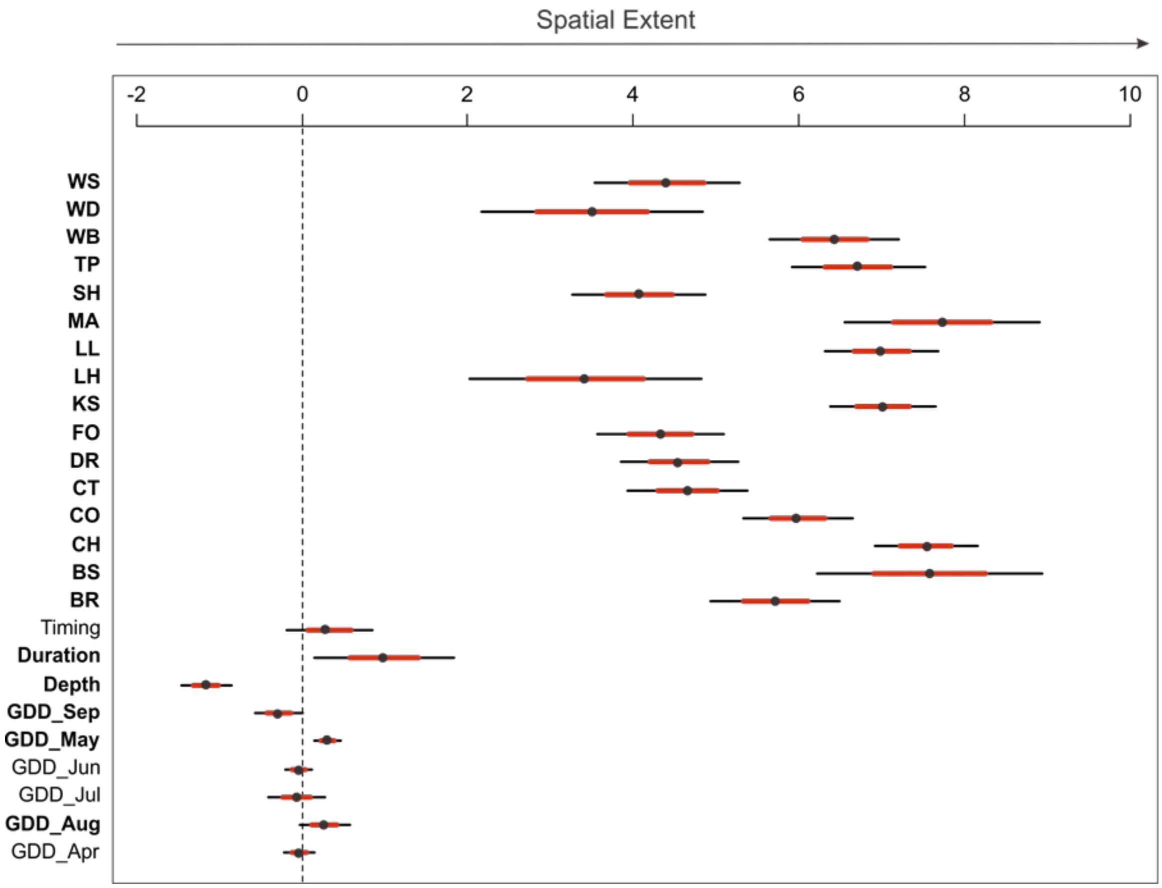


Figure 5-12: **Coefficient plots showing the value of the standardized regression coefficient (black rectangles) ± 2 SE (red line) for each fixed effect included in the GLMM, along with the 95 per cent confidence interval (horizontal black lines) for fixed effects, including growing degree days (GDD) 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 expanded in Table 4-2.

5.2.2 Community Richness and Diversity Across Landscape Units

Following some reductions after 2007 (which partly reflect mapping changes), the number of VCCs mapped per LSU and year has remained stable or increased over time (e.g., Sullivan Arm, Mount Blackman). Three LSUs increased in 2018 relative to 2016 (KM 79, Sprague Bay, and Mount Blackman). 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 5-13).

Aside from some reductions in 2007 (e.g., Beavermouth and Yellow Jacket Creek) that may reflect mapping changes, VCC diversity has remained generally stable over time with the possible exception of Sullivan Arm, where VCC diversity appeared to decrease in 2018 (Figure 5-14).

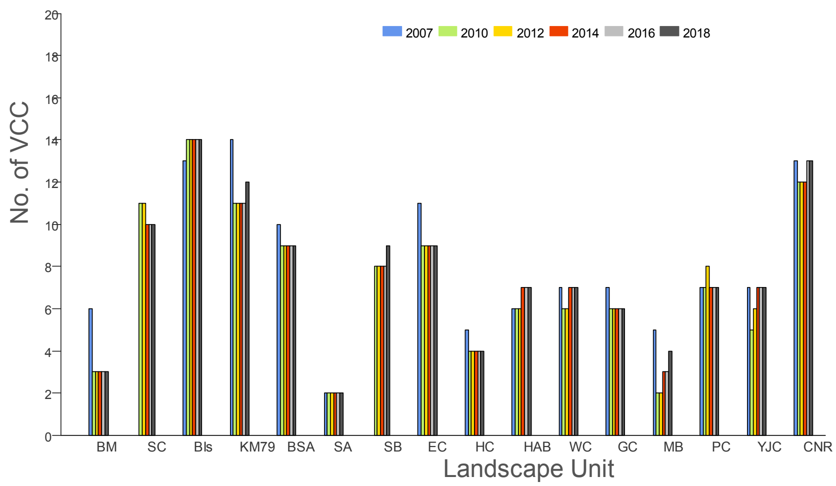


Figure 5-13: Number of vegetation communities mapped per landscape unit from 2007 to 2018. Landscape units are ordered south to north: BM = Beavermouth; Bis= Bear Island; KM79 = KM 79; BSA = Bush Arm; SC = Succour Creek; SA = Sullivan Arm; SB = Sprague Bay; EC = Encampment Creek; HC = Howard Creek; HAB = Hugh Alan Bay; WC = Windfall Creek; GC = Grouse Creek; MB = Mount Blackman; PC = Ptarmigan Creek; YJC = Yellow Jacket Creek; CNR = Canoe Reach.

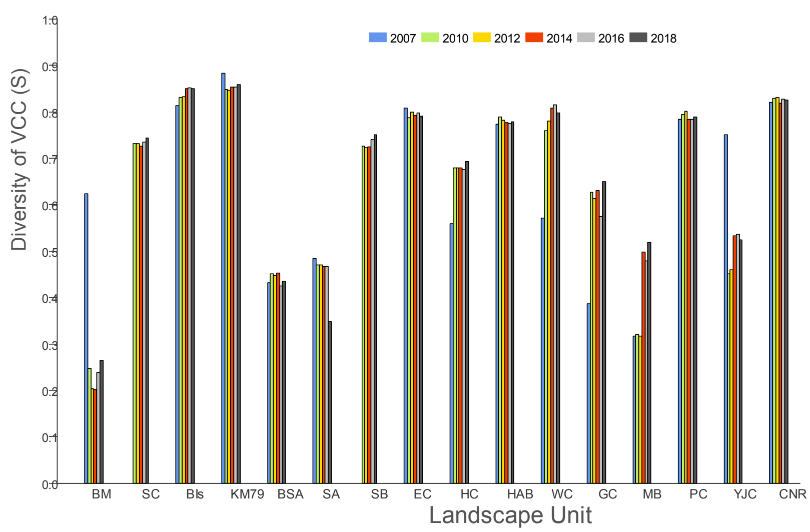


Figure 5-14: Diversity (Simpson's index) of vegetation communities mapped per landscape unit from 2007 to 2016. Landscape units are ordered south to north: BM = Beavermouth; Bis= Bear Island; KM79 = KM 79; BSA = Bush Arm; SC = Succour Creek; SA = Sullivan Arm; SB = Sprague Bay; EC = Encampment Creek; 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.

Table 5-2 details the changes in VCCs mapped for each landscape unit between 2007 and 2018. In general, the same communities were sampled in 2010, 2012, 2014, 2016, and 2018. See Figure 5-11 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 following 2007, and increases in 2012 and 2014 (e.g., at Ptarmigan Creek and Yellow Jacket Creek), are primarily related to improvements in mapping that occurred in 2012.

6.0 DISCUSSION

6.1 Summary

CLBMON-57 is a one-year program to assess the vegetation effects of increased water levels in Kinbasket Reservoir on the upper drawdown zone (i.e., 753 to 754 m ASL) resulting from future operation of Mica Units 5 during the summer refill period. The 2018 field season also represented the seventh year of a drawdown zone vegetation monitoring program that was in initiated in 2007 under CLBMON-10.

6.2 Species Richness, Diversity, and Per Cent Cover

The highly dynamic conditions within Kinbasket Reservoir present pose numerous challenges to quantifying the direction and magnitude of change that vegetation communities are experiencing; nevertheless, analyses performed in 2018 revealed some interesting patterns in species richness, diversity, and spatial extent:

- Species richness and diversity vary by landscape unit;
- Species richness and diversity have decreased with time (years);
- Species richness and diversity decrease as slope increases;
- Species richness and diversity increase with elevation;
- Species richness and diversity are positively correlated with an increase in GDD in September (2016 and 2018 results) and August (2016 results);
- Herb cover in the upper elevation bands (> 752 m ASL) decreases with increasing depth of inundation and increased growing degree days (GDD) in July and August, but increases with increasing September GDD (i.e., with increased exposure and/or warmth during this month); and
- Shrub cover in the upper elevation bands (> 752 m ASL) decreases with increased duration of inundation and, in contrast to herbs, increases with increased July GDD.

Hawkes et al. (2013) discussed vegetation community dynamics in the context of vegetation communities that appeared to be trending in nonparallel directions. Recent 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 slightly over time in communities situated at elevations ≥ 750 m ASL. The decline has been more apparent since 2012 following two successive years of reservoir surcharge and periods of increased 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. Given these results, it appears that community dynamics are subtly, but negatively, influenced by high water years and this trend is more apparent at elevations > 748 m ASL.

Table 5-1: Presence of VCCs 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 VCCs mapped per year at each landscape unit (LSU), and the total row indicates the years VCCs were sampled in given LSUs. The grand total corresponds to the total number of VCCs that were mapped over the five years. LSUs are ordered from south to north, and VCCs from pioneering to late seral stages. Community codes are defined in Table 4-2. Disturbed (DI) and Shrub Willow (SW) are not used in this analysis.

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	
Beaver Mouth	2007																						6
	2010																						3
	2012																						3
	2014																						3
	2016																						3
	2018																						3
	Total		6			1				6		1			1			6					6
Succour Creek	2007																						
	2010																						11
	2012																						11
	2014																						10
	2016																						10
	2018																						10
	Total	5	5	5		5	5			5	5			5	2			5	5				11
Bear Island	2007																						13
	2010																						14
	2012																						14
	2014																						14
	2016																						14
	2018																						14
	Total	6	6	6	6	6	5			6	5	6	6	6	6	1		6	6				15
KM 79	2007																						14
	2010																						11
	2012																						11
	2014																						11
	2016																						11
	2018																						12
	Total	6	6	6	2	6	6			6	6	6		6	1	1		6	6				14
Bush Arm	2007																						10
	2010																						9
	2012																						9
	2014																						9
	2016																						9
	2018																						9
	Total	6	6	1		6				6		6		6	6			6	6				10
Sullivan Arm	2007																						2
	2010																						2
	2012																						2
	2014																						2
	2016																						2
	2018																						2
	Total		6			1				5													3
Sprague Bay	2007																						
	2010																						8
	2012																						8
	2014																						8
	2016																						8
	2018																						9
	Total	5	1			5				5	5			5	5			5	5				9
Encampment Creek	2007																						12
	2010																						9
	2012																						9
	2014																						10
	2016																						10
	2018																						9
	Total	6	6	6		6	1			6	6	1			6		1	6	6			2	13
Howard Creek	2007																						5
	2010																						4
	2012																						4
	2014																						4
	2016																						4
	2018																						4
	Total		6			6				1					1			5	6				6
Hugh Alan Bay	2007																						6
	2010																						6
	2012																						6
	2014																						7
	2016																						7
	2018																						7
	Total	6	6			6	6			6		1						5	3				8
Windfall Creek	2007																						7
	2010																						6
	2012																						6
	2014																						7
	2016																						7
	2018																						7
	Total	6	6			6				6		1			6			6	3				8
Grouse Creek	2007																						8
	2010																						6
	2012																						6
	2014																						6
	2016																						6
	2018																						6
	Total		6			6				1					6	6	1	6	6				8
Mount Blackman	2007																						5
	2010																						2
	2012																						2
	2014																						3
	2016																						3
	2018																						4
	Total	1	6							6					1			2	3				6
Ptarmigan Creek	2007																						7
	2010																						7
	2012																						8
	2014																						7
	2016																						7
	2018																						7
	Total	6	6	6		6				6					6			1	6				8
Yellowjacket Creek	2007																						7
	2010																						5
	2012																						6
	2014																						7
	2016																						7
	2018																						7
	Total	1	6			6	6			6					6			4	4				8
Canoe Reach	2007																						13
	2010																						12
	2012																						12
	2014																						12
	2016																						13
	2018																						13
	Total	6	6	6		6	6			6	5	6	5	6	3	1		6	1	6			15

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 5-15), 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 (Hawkes 2015). The prevailing wind in Bush arm is from west to east, thus 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.

6.3 Spatial Extent of Vegetation

- The total spatial extent of mapped vegetation has increased slightly with time;
- Extents of different vegetation communities have changed in different directions over time, depending on community;
- Vegetation extents of different landscape units have changed in different directions over time;
- Spatial extent of vegetation is maximal at medium-low elevation (745 m ASL) in the drawdown zone;
- Spatial extent of vegetation was positively correlated with inundation duration but decreased significantly with water depth; and
- Spatial extent of vegetation was higher when GDD were higher in May and August, but lower when GDD were higher in September.

Landscape-level vegetation mapping indicates that the spatial extent of vegetation has varied over time, registering a 9 per cent increase overall since 2007, although some individual LSUs have experienced a decreasing trend over that time. The variation in type and direction of change observed at both the VCC and LSU scales is indicative of the dynamic nature of processes influencing the drawdown zone environment. 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 unit, different vegetation communities may be affected differently. The individual effects of fetch and wood debris scour on each vegetation community at each landscape unit are not directly measurable (due to the sampling intensity associated with CLMBON-10/57) and as such, neither are the complex interactions between reservoir elevations, fetch, and wood debris.

The spatial extent of communities varied with the number of growing degree days and inundation depth and duration. Spatial extent increased with increasing GDD in May and August, while decreasing with increased September GDD. Notably, spatial extent was predicted to decrease with increasing water depth but to increase with greater inundation duration. While the strength of some of these relationships is weak, they provide an indication of variables that may have contributed to 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 at the landscape scale. For example, when reservoir elevations are lower (i.e., water depth is lower), the number of growing degree days increases, and vegetation spatial extent tends to increase. These results imply that modifications to reservoir operations that reduce the depth of inundation would contribute to increases in the spatial extent of vegetation within the drawdown zone.

Since 2007, we have characterized and mapped 19 vegetation communities in the drawdown zone. The diversity of communities within each landscape unit, as well as the relative distributions of communities within landscape units, has remained more less stable with time. This, in combination with the slight but incremental increases over time in the total spatial extent of mapped vegetation, implies that the current operating regime is succeeding in maintaining the general character, composition, and extent of vegetation at the landscape scale.

6.4 Mica 5 Impacts

Since the 2016 entry in operation of Mica 5, reservoir maximums have remained comparatively low relative to those experienced during the decade prior. This means that a large segment of drawdown vegetation has not yet been subjected to any additional inundation cycles directly (or indirectly) ascribable to Mica 5 operation. To better assess the possible effects on upper-elevation vegetation of increasing reservoir levels by 60 cm in 3 out 10 years (the anticipated hydroregime change associated with Mica 5), three different operational scenarios were modeled using simulations. The three scenarios differed with respect to the timing and duration of the 60 cm increase in reservoir level. Each scenario was applied to the following vegetation parameters: total herb cover; total shrub cover; cover and frequency of sedges (*Carex* spp.); and cover and frequency of willows (*Salix* spp.). Simulation results were then compared to each other and to baseline models for each parameter.

Simulations produced highly similar, and statistically non-distinguishable, results for each scenario modelled and compared to the baseline. Models failed to detect any notable effects on herb or shrub cover, or on sedge or willow frequencies, from increasing reservoir elevations by 60 cm in 30% of years. Acknowledging that the available data set is limited in terms of size and scope, it appears that any potential vegetation impacts associated with a semi-periodic increase in reservoir levels by 60 cm are likely to be swamped by the environmental noise of much larger inter-annual fluctuations in inundation depth and duration.

Figure 4-1 and Figure 4-2 illustrate how summer peak levels in Kinbasket Reservoir have varied over the period of study. 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. In 2018, reservoir elevations were much lower than the 40-year average and all other year of sampling associated with CLBMON-10 from late July onward.

Table 6-1 shows the proportion of time that the water levels exceeded a given elevation band during the growing season; 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.

Table 6-2: **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	0.00	0.37	0.40	0.18	0.16	0.19	0.38	0.43	0.35	0.37	0.00	0.37
752-753	0.00	0.00	0.36	0.00	0.06	0.03	0.35	0.42	0.30	0.34	0.00	0.02
753-754	0.00	0.00	0.19	0.00	0.00	0.01	0.32	0.32	0.25	0.29	0.00	0.00
>754.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.14	0.00	0.00	0.00

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 ASL was < 1 m, with surcharge lasting for 32 days in 2012 and 26 days in 2013). 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.

Table 6-3: **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	0.00	0.63	2.10	0.75	0.84	0.57	2.43	2.78	2.62	2.12	0.00	0.71
752	0.00	0.00	1.24	0.00	0.10	0.50	1.58	1.84	1.97	1.28	0.00	0.07
753	0.00	0.00	0.78	0.00	0.00	0.00	0.68	1.23	1.25	0.41	0.00	0.00
754	0.00	0.00	0.18	0.00	0.00	0.00	0.06	0.46	0.45	0.00	0.00	0.00
>754.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.00	0.00	0.00

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 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 situated at 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, as noted above, we have observed slight 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 (Hawkes and Gibeau 2017).

The depth and duration of inundation are also determining factors with respect to vegetation per cent cover in the upper elevation bands. Based on GLMM results, herb cover within this zone was predicted to decline with increasing inundation depth, while shrub cover was predicted to decline with increasing time under water. The interaction between depth and duration and their effects on vegetation cover and extent are likely more important than either one alone, but this has not been explicitly tested and is challenging or even impossible in the absence of an opportunity to manipulate one or both variables. Predicted relationships between cover and monthly GDD, which weight exposure time by the availability of “growth-conducive” ambient temperatures (thus equating with actual growing time) during the preceding year, indicate that herb cover should be favoured by increased exposure and warmth in September. In contrast, and somewhat counterintuitively, herb cover appears to be negatively affected by warm, exposed conditions in July and August of the previous year (for purposes of this discussion we disregard GDD accruing prior to July since these reflect only ambient temperatures, not inundation variables). This result may reflect the sensitivity of inundation-adapted vegetation to mid-summer dry stress. Due to the low water-holding capacity of the gravelly to sandy substrates that cover much of the drawdown zone, and the distance to the water table in many locations, summer drought conditions are a common characteristic of this environment.

There does appear to be a balance between too much inundation (in terms of depth and duration) and not enough inundation, with cursory results from a fall survey in 2015 suggesting that some mid-summer inundation may be beneficial, and even critical, to plant survivorship and vigor (Miller and Hawkes, unpubl. data). In a related survey, Miller *et al.* (2016) reported that brief periods of shallow inundation (~ one week) in Arrow Lakes Reservoir 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 (Miller *et al.* 2016).

In summary, simulation models predicted minimal to neutral effects on vegetation cover or diversity stemming from operational changes related to Mica 5 implementation (models were predicated on a 60 cm increase in water levels in three out of 10 years). That said, results from the past decade of monitoring imply that a regime of frequent high-water events, or high-water events of extended late-summer duration, have the clear potential to exert a detrimental impact on existing vegetation communities (both in terms of composition and aerial extent) within the top elevation bands of the drawdown zone. Thus, the predicted impacts of Mica 5 operation could change if, over time, operation results in reservoir elevation increasing by > 60 cm or increasing by 60 cm more often than thrice in 10 years. More subtly, the predicted impact *relative to baseline conditions* could change (increase) under the following hypothetical but possible scenarios:

- If, during a sequence of otherwise moderate water-level years (baseline reservoir maximums < 752 m ASL), operation of Mica 5 results in repeated inundation of upper elevation bands > 752 m ASL (i.e., Mica 5 operation results in a "tipping of the scales" between inundation and non-inundation for high elevation, inundation-sensitive vegetation);
- If operation of Mica 5 results in a significant increase in the duration of inundation for affected elevation bands, relative to the baseline (leading possibly to increased rates of plant anoxia, erosion, sedimentation, wood debris deposition, etc.); and/or
- If operation of Mica 5 results in systematic, directional changes to the timing of inundation (e.g., if operation shifts the average timing of inundation to earlier or later in the growing season) such that established plant life-history cycles of germination, growth, flowering, and recruitment are compromised relative to baseline conditions.

CLBMON-10 was designed to answer management questions specific to that program. As such, the CLBMON-10 sampling scope was not specifically geared to gathering the data needed to model the impacts of a predefined hydroregime change on the vegetation of the uppermost elevation bands. Furthermore, the reservoir inundation cycles experienced by vegetation between 2007 and 2018 were unreplicated in time and space, limiting the predictive power of those data. In this study, we have co-opted the available CLBMON-10 data (supplemented by an additional season of more focused data collection under CLBMON-57) to model those impacts to the extent possible under the CLBMON-57 project scope. However, our predictions of minimal to no impact based on data simulations may require verification through follow-up monitoring.

7.0 CONCLUSIONS

Since the entry in operation of Mica 5 in 2016, reservoir maximums have remained low relative to those experienced during the decade prior. Based on simulations applied to available data, we found no detectable effects on total vegetation cover, or on sedge or willow frequencies, accruing from the entry in operation of Mica Generating Unit 5. This result should not be interpreted to mean that vegetation parameters are not sensitive to the anticipated increases in reservoir elevation associated with Mica 5 operation; rather, it more likely indicates that the biological effects of a semi-periodic increase in reservoir levels by 60 cm are obscured by the background noise of larger inter-annual fluctuations in inundation depth and duration that have prevailed since 2007. As such, predictions of minimal to no effect based on data simulations should be verified through further post-entry monitoring.

Regarding CLBMON-10 management questions, many of the conclusions reached in the final implementation year of CLBMON-10 (Hawkes and Gibeau 2017) were supported in this single implementation year for CLBMON-57. At the landscape level, vegetation mapping based on remote sensing indicates that some vegetation communities have increased slightly in mapped extent since 2007, while others have decreased slightly. However, the total extent of mapped vegetation has registered a slight increase since 2007 (from ~2021 ha to ~2199 ha).

At the local site level, species compositions have undergone some turnover since 2007 and there has been a general, though variable, decrease over time in species richness and diversity within several monitored vegetation communities. 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. Although ongoing 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 > 750 m ASL if operations repeat the inundation cycles observed between 2007 and 2014.

At the recent 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 unlikely to ever achieve equilibrium because they will be continuously responding 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 to 2018), there is some 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 GLMM models that predict that 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. Our observations suggest that the largest changes will occur at higher elevations (> 750 m ASL) on moisture-retaining substrates in areas free of wood debris accumulation.

Predictive models (GLMMs) provide insight into the operational and environmental factors that influence vegetation communities in the drawdown zone of Kinbasket Reservoir (e.g., slope, temperature, wind, and frequency, timing, duration, and depth of inundation), while showing that the interactions between these factors are likely more important than any single factor. Each of these aspects can influence growing times, rates of erosion, sedimentation, and wood debris accumulation and scour. Because none of these factors, with the exception of wood debris, has been directly manipulated, it remains a challenge to quantify the specific effect that changes to most operational factors would have on the extent and occurrence of vegetation growing in the drawdown zone of Kinbasket Reservoir. However, evidence from other programs (e.g., CLBWORKS-01; CLBMON-09) does point to the benefits of wood debris removal on the establishment and development of vegetation communities, while observational data support the notion that some level of short-term inundation is beneficial to—and likely necessary for—inundation-adapted 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. 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.

8.0 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 wood 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. and V.C. Hawkes. 2015. Moss Grass (*Coleanthus subtilis*) Survey, Upper Revelstoke Reach – Summary Report, June 2015. LGL Report EA3632. Unpublished report by LGL Limited environmental research associates, Sidney, B.C., for B.C. Hydro Generation, Revelstoke Unit 6 Project and Water Licence Requirements, Burnaby, BC. 14 pp.

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.

9.0 APPENDICES

9.1 Supporting Results

Community Composition

Table 9-1. **Groups of concordant species produced by Kendall Concordance analysis (group 1 [56 species]: $W = 0.217$, $F = 1.52$, $p < 0.00001$; group 2 [26 species]: $W = 0.394$ $F = 1.62$, $p < 0.00001$).** 7-letter species codes are from the BC provincial flora checklist.

Group	Concordant species
1	AGROGIG, AGROSCA, ANAPMAR, CALACAN, CALASTR, CAREQAU, CARECRW, CAREFLA, CAREINT, CARELAS, CARESTI, CAREUTR, CASTMIN, CERAFON, CICUDOU, COMAPAL, CREPTEC, ELYMREP, EPILANG, EPILCII, EQUIFLU, EQUIVAR, FRAGVIR, GALETET, GALITRD, GEUMMAC, GLYCSTR, HIERCAE, HIERPIO, JUNCALP, JUNCNOD, LEUCVUL, LYSITHY, MELIALB, MENYTRI, MIMUGUT, PHALARU, POA COM, POA PAL, POA PRA, PRUNVUL, RHINMIN, RUBUPUB, RUMECRI, SCIRATR, SCIRMIC, TARAOFF, TRIFAUR, TRIFHYB, TRIFPRA, VIOLMAC
2	BIDECER, CALLPAL, CARDPEN, CERANUT, CHENALB, COLLLIN, DESCDAN, ERYSCHE, GNAPULI, JUNCBUF, JUNCENS, JUNCFIL, MATRDIS, MYOSSCO, PERSHYD, PERSMAC, PLAGSCO, POLYAVI, POTENOR, RANUPEN, RANUSCE, RORIPAL, SPERRUB, TRIFREP, VEROBEC, VEROPER2

Cumulative Species

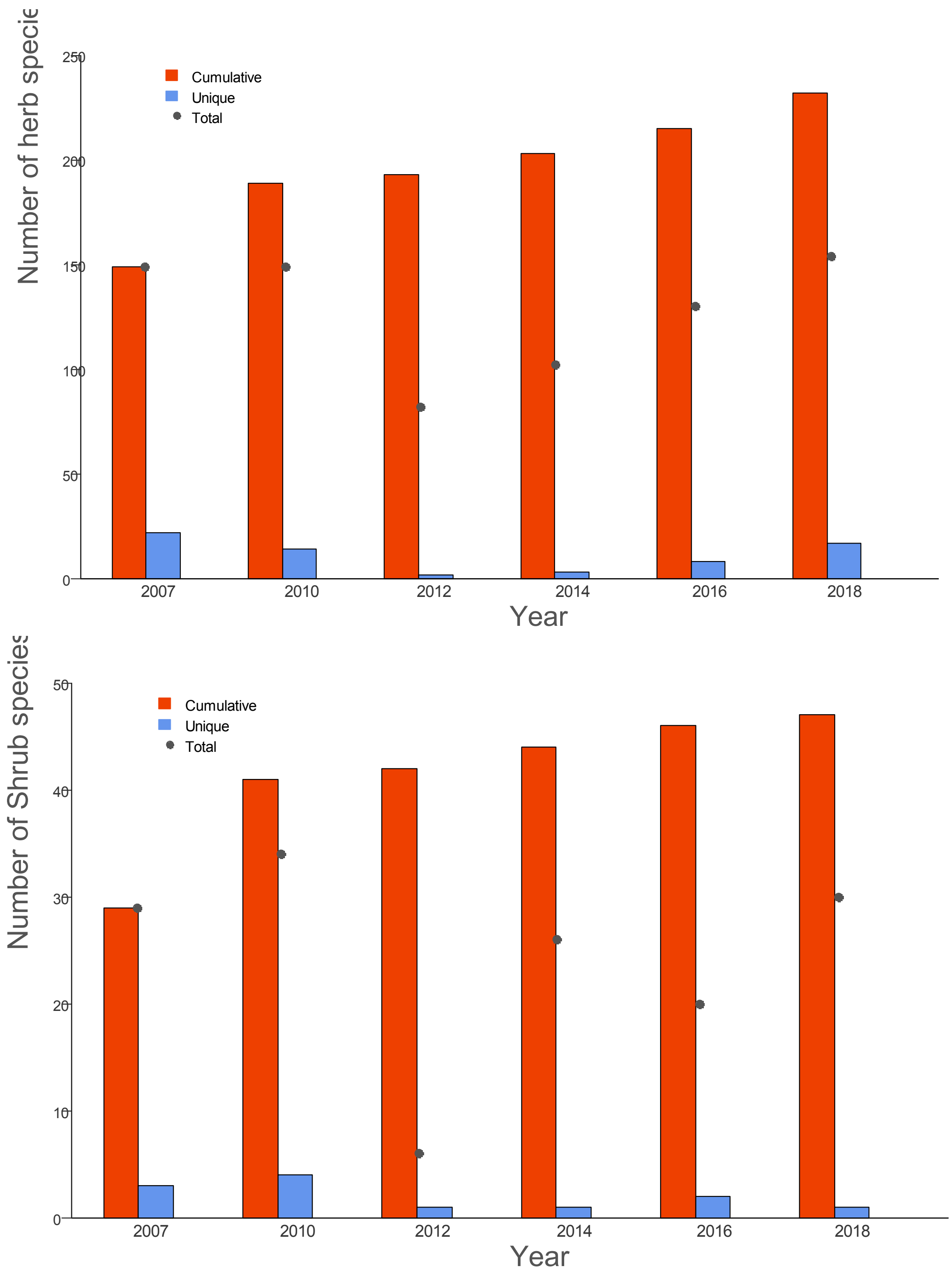


Figure 9-1: **The cumulative number of vascular plant species recorded in sample transects in the Kinbasket Reservoir drawdown zone since 2007 (top: herb layer; bottom: shrub/tree layer), in transects sampled in at least two years.** The number of unique species (those recorded in just one year) and the total number of species recorded in a year are also shown.

Species Constancy

Table 9-2: Herb (upper table) and shrub/tree (lower table) species constancy within vegetation communities sampled from 2007 to and 2018. Only resampled transects were considered (i.e., transects newly established in 2018 not included). Note: different numbers of transects were sampled per community in each year. Percent constancy was calculated as the proportion of all herbs present in 2018 that were recorded in at least one of the previous sample years. Refer to Table 4-2 for vegetation community definitions.

VCC	Number of herb species observed in…										# herb species in 2018	Total # of herb species (overall)	% constancy
	2007 only	2010 only	2012 only	2014 only	2016 only	2018 only	3/6 years	4/6 years	5/6 years	All 6 years			
LL	2	11	2	3	0	4	6	7	5	7	25	52	84
CH	3	16	1	1	7	4	13	14	7	10	42	92	90
TP	3	1	0	1	--	7	1*	5*	--	13*	26	38	73
MA	8	1	2	2	4	1	5	5	1	7	11	43	91
KS	3	5	2	5	6	5	9	16	15	14	59	99	92
BR	16	2	--	7	11	2	9*	8*	--	5*	20	72	90
CO	17	4	0	3	4	9	11	19	17	3	73	129	88
WB	1	2	3	2	3	8	9	9	13	8	40	67	80
SH	3	5	0	3	3	4	7	4	4	6	21	49	81
BS	3	2	3	0	9	3	4	6	9	2	26	48	88
WS	10	7	0	1	4	9	9	10	14	8	48	93	81
CT	4	8	0	3	6	7	5	8	0	4	28	56	75
LH	8	3	--	--	3	0	--	--	--	1*	1	16	100
DR	--	1	10	1	4	14	2*	2*	2*	--	21	40	33

* some years not sampled so totals are on 4 or 5 years

VCC	Number of shrub or tree species observed in…						# species in 2018	Total # (overall)	% constancy
	2007 only	2010 only	2012 only	2014 only	2016 only	2018 only			
LL	0	0	0	1	0	0	0	1	--
CH	0	4	0	2	1	0	0	13	--
KS	0	1	0	1	1	0	0	4	--
BR	0	0	0	0	0	0	1	7	100
CO	4	4	0	0	0	3	10	23	70
WB	0	0	1	0	0	0	0	1	--
SH	0	0	0	0	0	0	1	2	100
WS	5	2	1	0	1	1	13	27	92
CT	1	4	0	1	0	4	16	23	75
LH	5	0	0	0	0	0	0	5	--
DR	0	0	0	1	0	4	5	6	20
FO	0	0	1	0	0	0	0	1	--
MC	10	0	0	0	0	0	0	12	--
RD	0	0	0	0	1	0	3	4	100

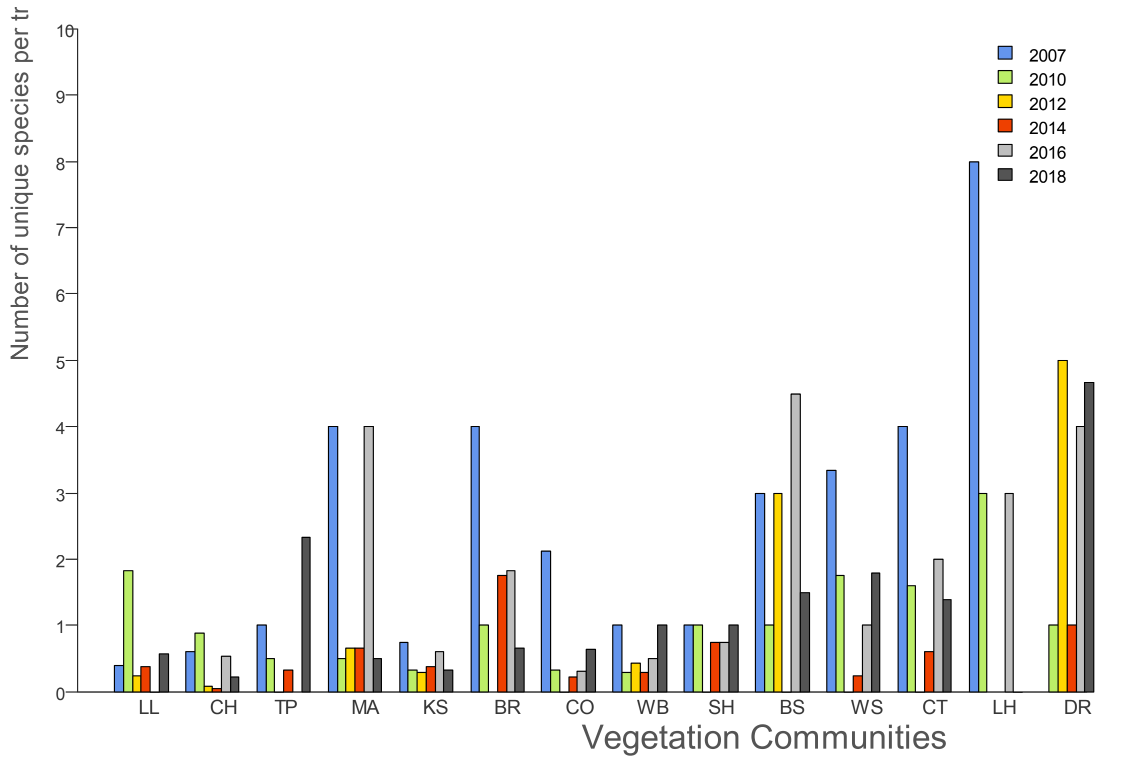
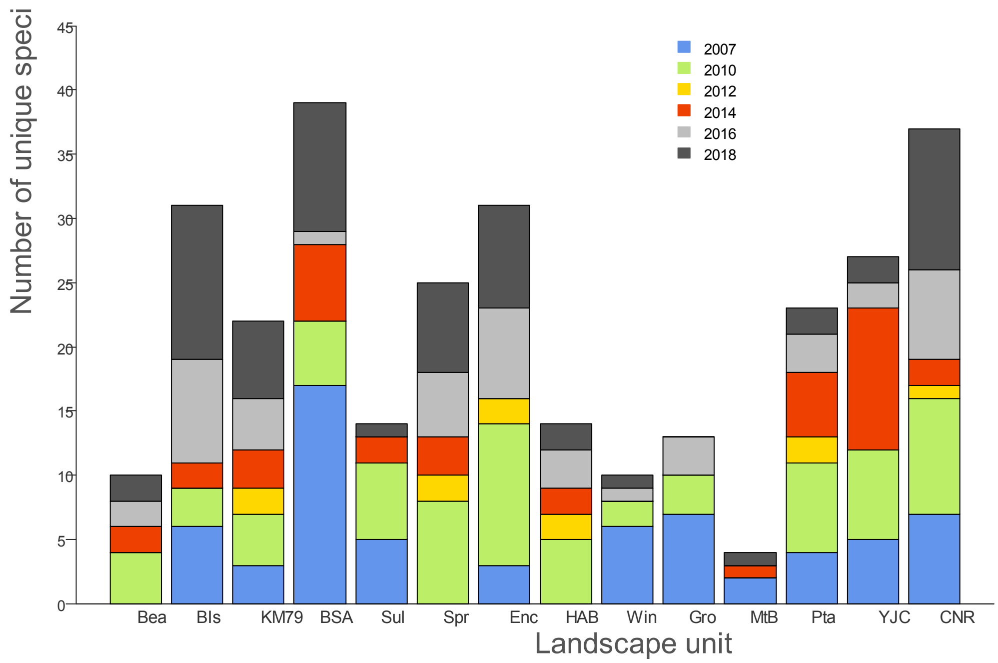


Figure 9-2: Number of species unique to a vegetation community over time, corrected for the number of transects sampled each year.



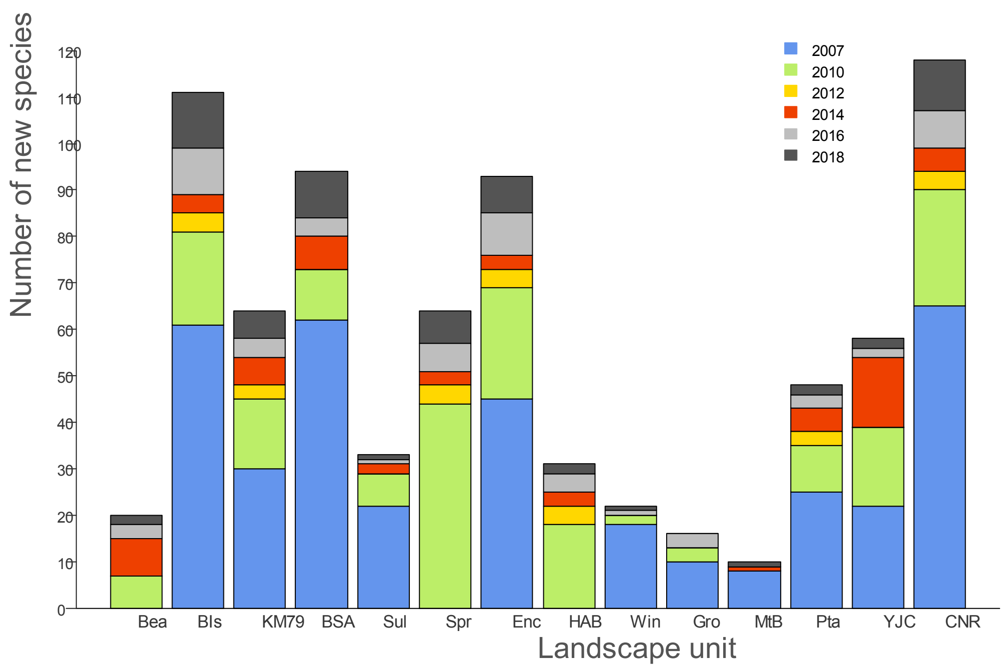


Figure 9-3: **Number of unique herb species (top) and new herb species (bottom) recorded in each landscape unit in the 2018 transects repeated over time (2007, 2010, 2012, 2014, 2016, and 2018).** Bea = Beaver Mouth, Bis= Bear Island, KM79 = KM 79, BSA = Bush Arm; Sul = Sullivan Arm; Spr = Sprague Bay; 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.

Species richness and Diversity

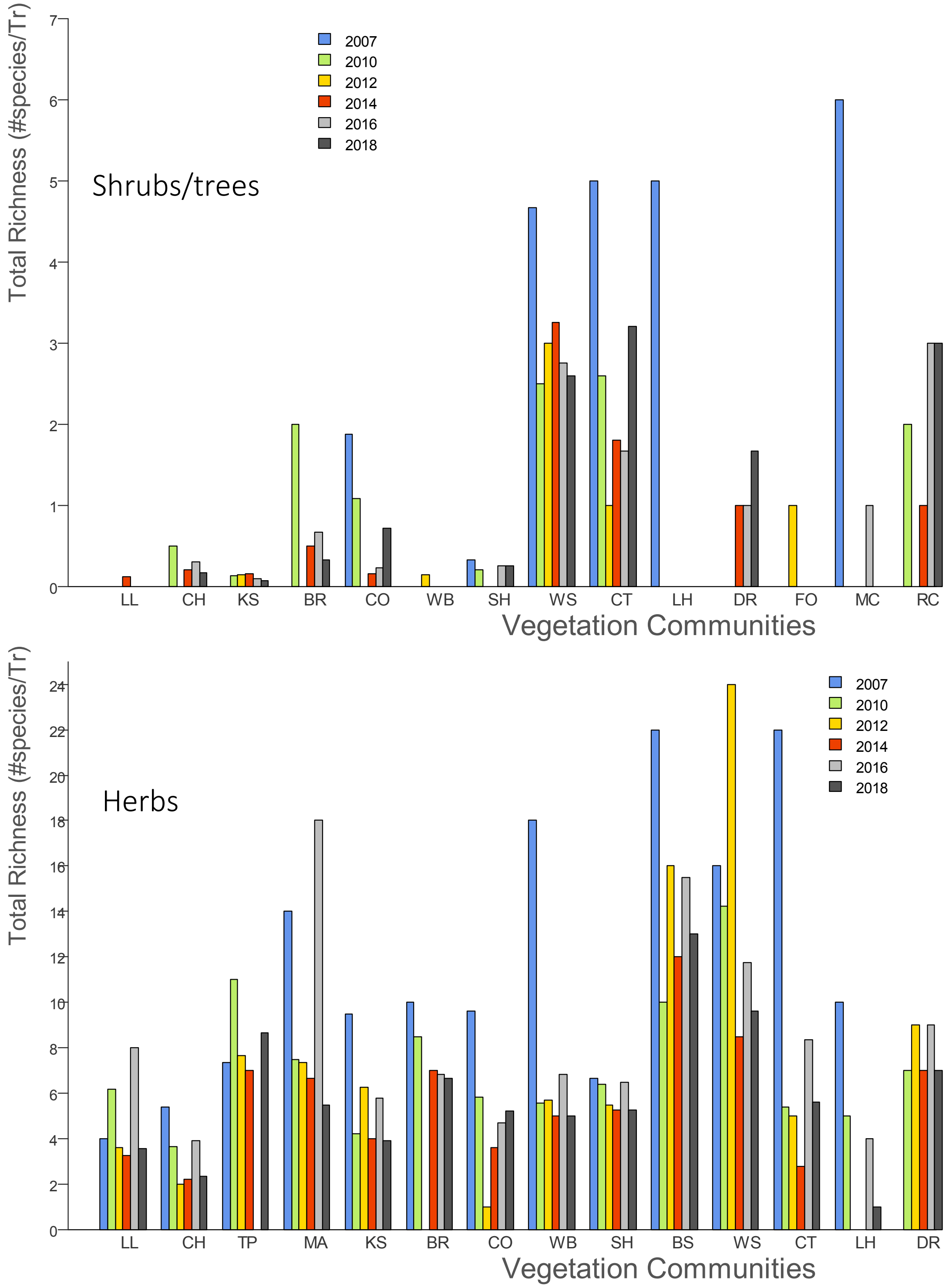


Figure 9-4: **Species richness of transects (bottom panel: herbs; top panel: shrubs and trees), after controlling for the number of transects sampled, per vegetation community in sampled years.** Refer to Table 4-2 for a description of the vegetation communities.

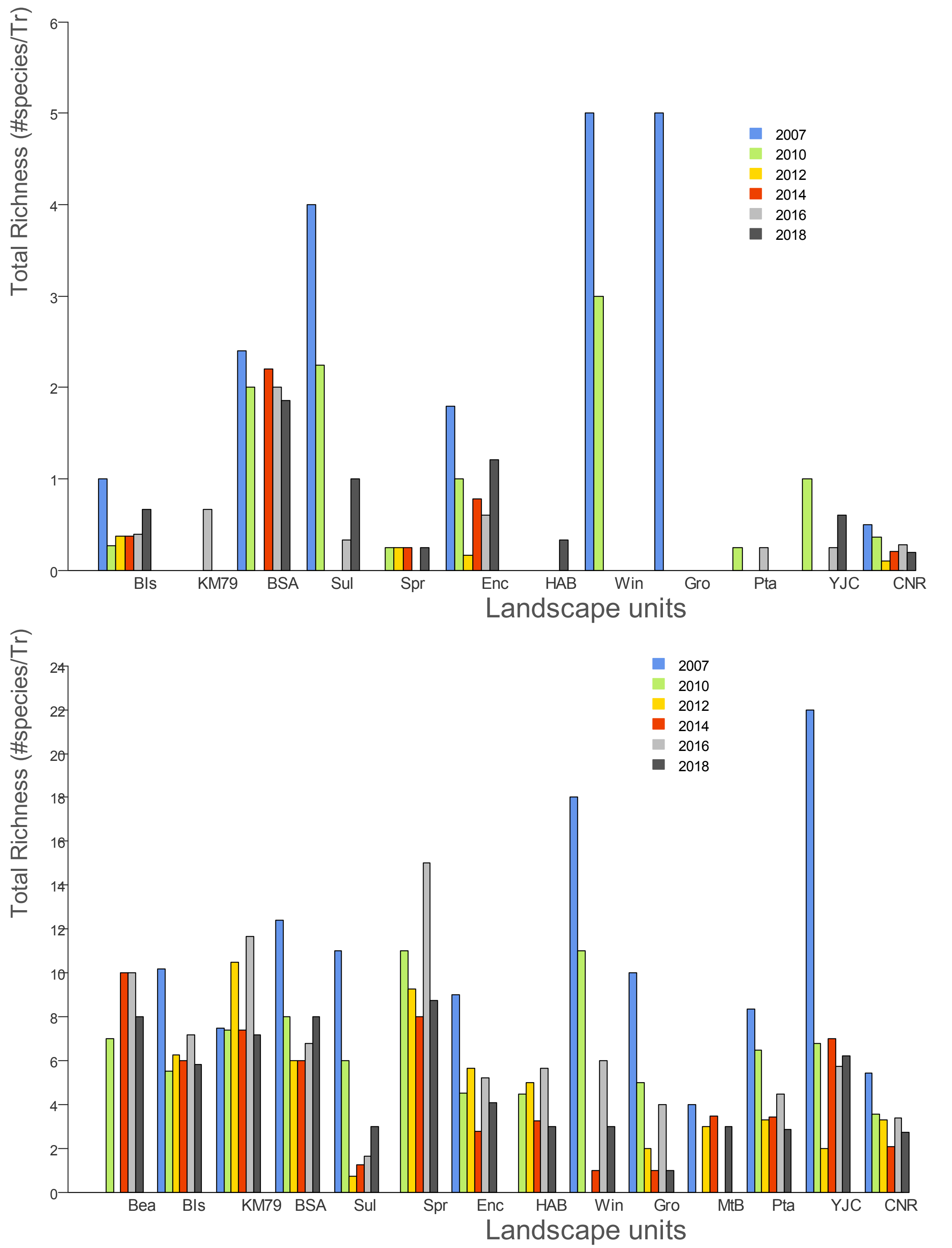
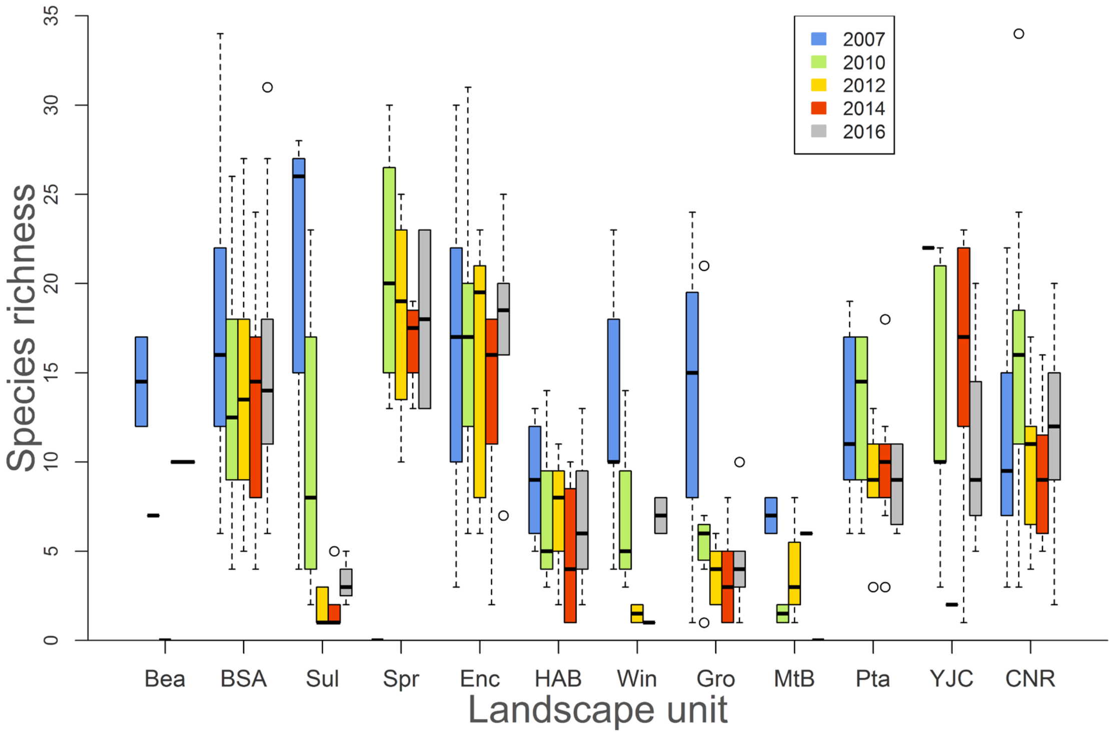


Figure 9-5: **Total species richness (bottom: herb layer; top: shrub/tree layer) per landscape unit corrected by sampling effort (number of transects) per landscape unit for transects sampled in 2018 and at least once prior (2007-2016) in Kinbasket Reservoir.** Landscape units were ordered from south to north.



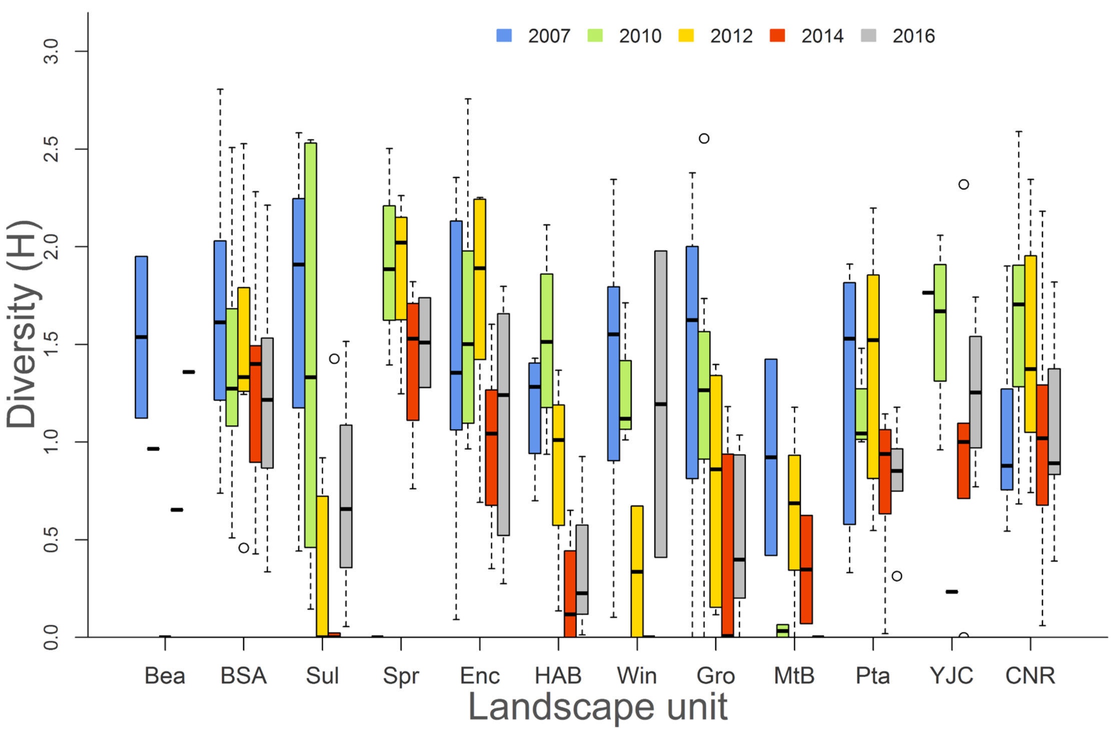


Figure 9-6: **Species richness (top panel) and diversity (Shannon's H, bottom panel) per transect in each landscape unit in 2007, 2010, 2012, 2014, 2014, and 2016.** Landscape units are ordered from south to north in Kinbasket Reservoir

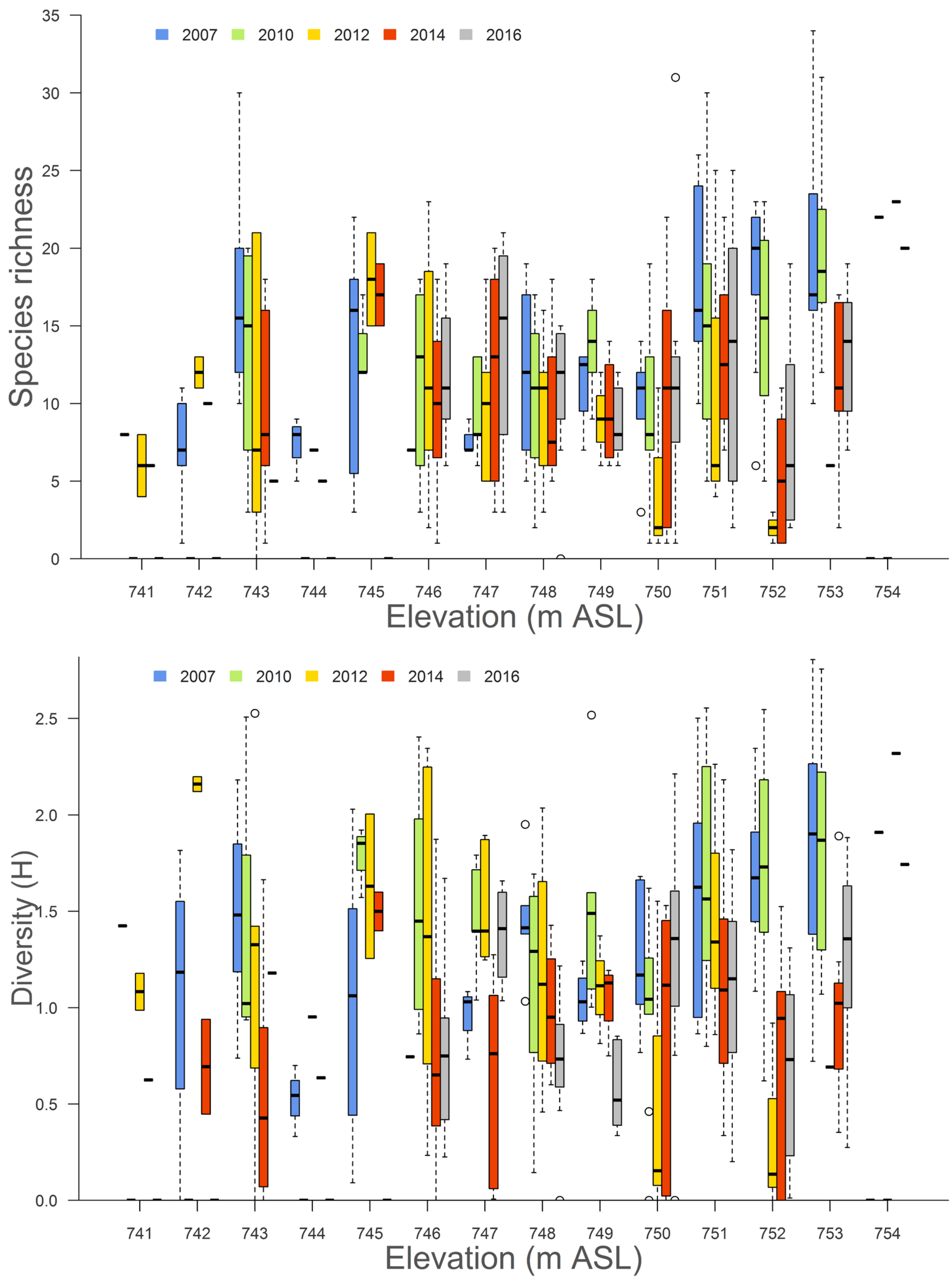


Figure 9-7: Species richness (top) and diversity (Shannon's H) of vegetation per transect in relation to elevation, over time

Mica 5 Predictive Modeling (Upper Elevation Bands)

Table 9-3: Summary statistics for Wald tests of regression coefficients associated with Figure 5-6. Critical level of alpha was set to 0.1 for tests of significance.

Vegetation Metric	Variable	Coefficient	Std. error	t-value	p-value
Total herb cover	Slope	-0.49	0.14	-3.41	0.001
	Heatload	0.20	0.14	1.43	0.157
	GDD_Apr	-0.72	0.23	-3.18	0.002
	GDD_May	-0.23	0.12	-1.86	0.0658
	GDD_Jun	2.08	0.52	3.98	0.0001
	GDD_July	-2.09	0.50	-4.17	0.0001
	GDD_Aug	-1.13	0.28	-4.02	0.0001
	GDD_Sep	1.14	0.38	3.03	0.0032
	Depth	-0.69	0.31	-2.18	0.0321
	Duration	0.18	0.32	0.56	0.5783
Total shrub cover	Slope	0.34	0.16	2.10	0.0388
	Heatload	0.03	0.16	0.19	0.8521
	GDD_Apr	-0.37	0.23	-1.60	0.1134
	GDD_May	0.06	0.12	0.51	0.6142
	GDD_Jun	-1.05	0.49	-2.12	0.0368
	GDD_July	0.79	0.47	1.66	0.0998
	GDD_Aug	0.19	0.28	0.69	0.4951
	GDD_Sep	-0.46	0.41	-1.13	0.2628
	Depth	0.21	0.32	0.67	0.506
	Duration	-1.12	0.36	-3.11	0.0026
Carex cover	Slope	-0.15	0.09	-1.61	0.1105
	Heatload	0.03	0.09	0.32	0.7479
	GDD_Apr	0.01	0.15	0.04	0.9701
	GDD_May	0.05	0.08	0.67	0.5025
	GDD_Jun	0.37	0.34	1.08	0.2828
	GDD_July	-0.35	0.33	-1.08	0.2838
	GDD_Aug	-0.15	0.19	-0.78	0.4357
	GDD_Sep	0.31	0.26	1.22	0.2238
	Depth	0.10	0.21	0.46	0.6457
	Duration	0.25	0.22	1.11	0.2716
Salix cover	Slope	0.24	0.19	1.27	0.2097
	Heatload	-0.04	0.19	-0.23	0.8214
	GDD_Apr	-0.22	0.26	-0.85	0.4005
	GDD_May	0.03	0.14	0.20	0.8388
	GDD_Jun	-0.93	0.52	-1.78	0.0808
	GDD_July	0.64	0.51	1.27	0.2094
	GDD_Aug	0.24	0.33	0.73	0.4709

	GDD_Sep	-0.35	0.45	-0.77	0.4457
	Depth	0.20	0.36	0.55	0.5835
	Duration	-0.78	0.40	-1.95	0.0556
Carex frequency	Slope	-0.18	0.10	-1.76	0.0828
	Heatload	-0.08	0.09	-0.82	0.4159
	GDD_Apr	0.20	0.20	1.03	0.3054
	GDD_May	0.24	0.11	2.12	0.0378
	GDD_Jun	-0.58	0.44	-1.30	0.2002
	GDD_July	0.57	0.43	1.32	0.1905
	GDD_Aug	0.13	0.24	0.53	0.5965
	GDD_Sep	-0.18	0.32	-0.56	0.5807
	Depth	0.28	0.30	0.94	0.3522
	Duration	-0.10	0.27	-0.36	0.7214
Salix frequency	Slope	0.05	0.15	0.31	0.7572
	Heatload	0.02	0.14	0.16	0.8746
	GDD_Apr	-0.42	0.22	-1.94	0.0615
	GDD_May	-0.14	0.11	-1.23	0.2266
	GDD_Jun	-0.50	0.32	-1.57	0.126
	GDD_July	0.55	0.34	1.61	0.1172
	GDD_Aug	0.09	0.26	0.33	0.7452
	GDD_Sep	-0.96	0.37	-2.62	0.0138
	Depth	-0.68	0.35	-1.96	0.0593
	Duration	-0.50	0.27	-1.84	0.0758

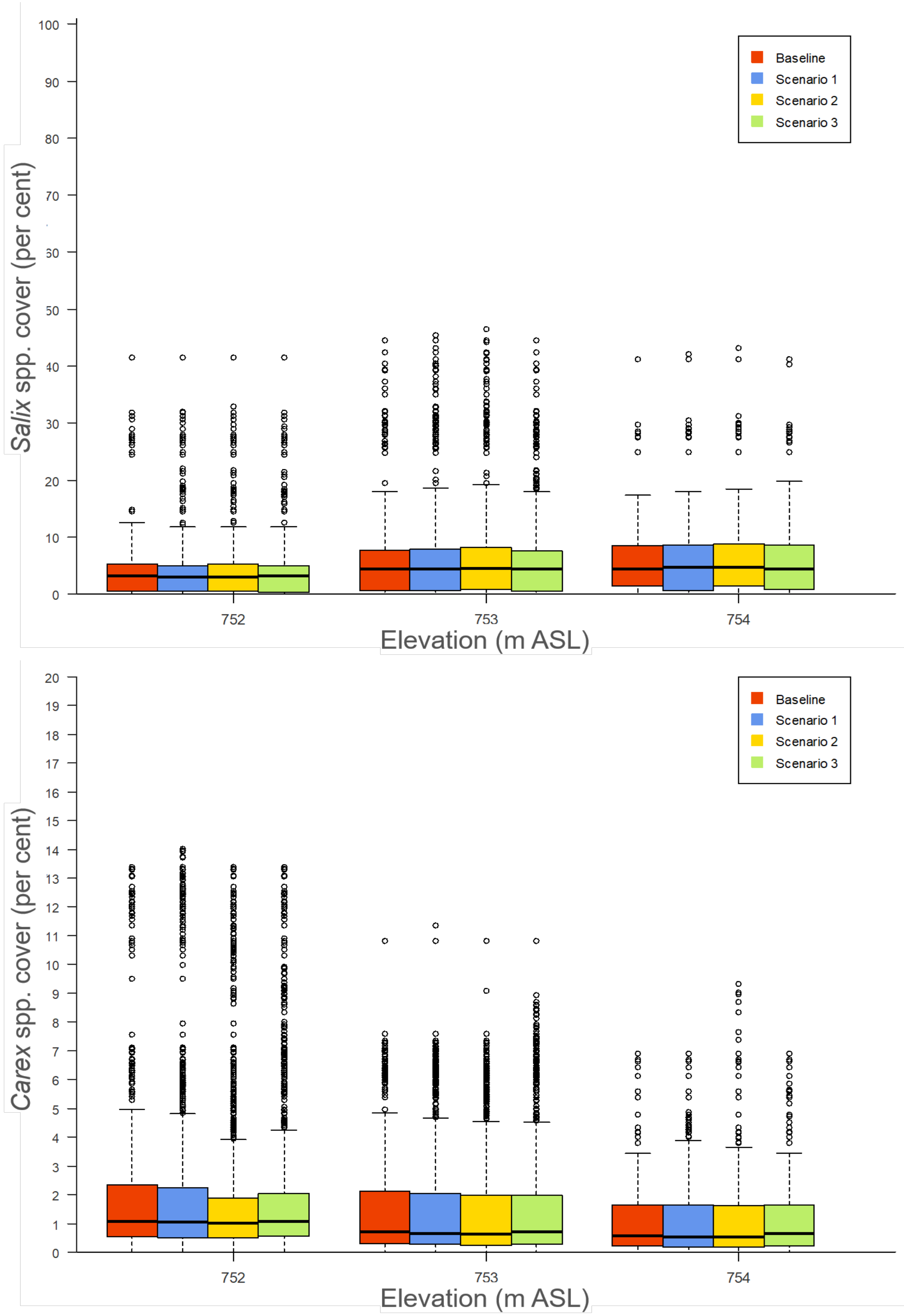


Figure 9-8: Variation in predicted per cent cover of *Carex* spp. (bottom panel) and *Salix* spp. (top panel) under baseline conditions and three scenarios of increased (+60 cm) reservoir elevations over 1000 simulations per elevation band. See Methods for scenario descriptions.

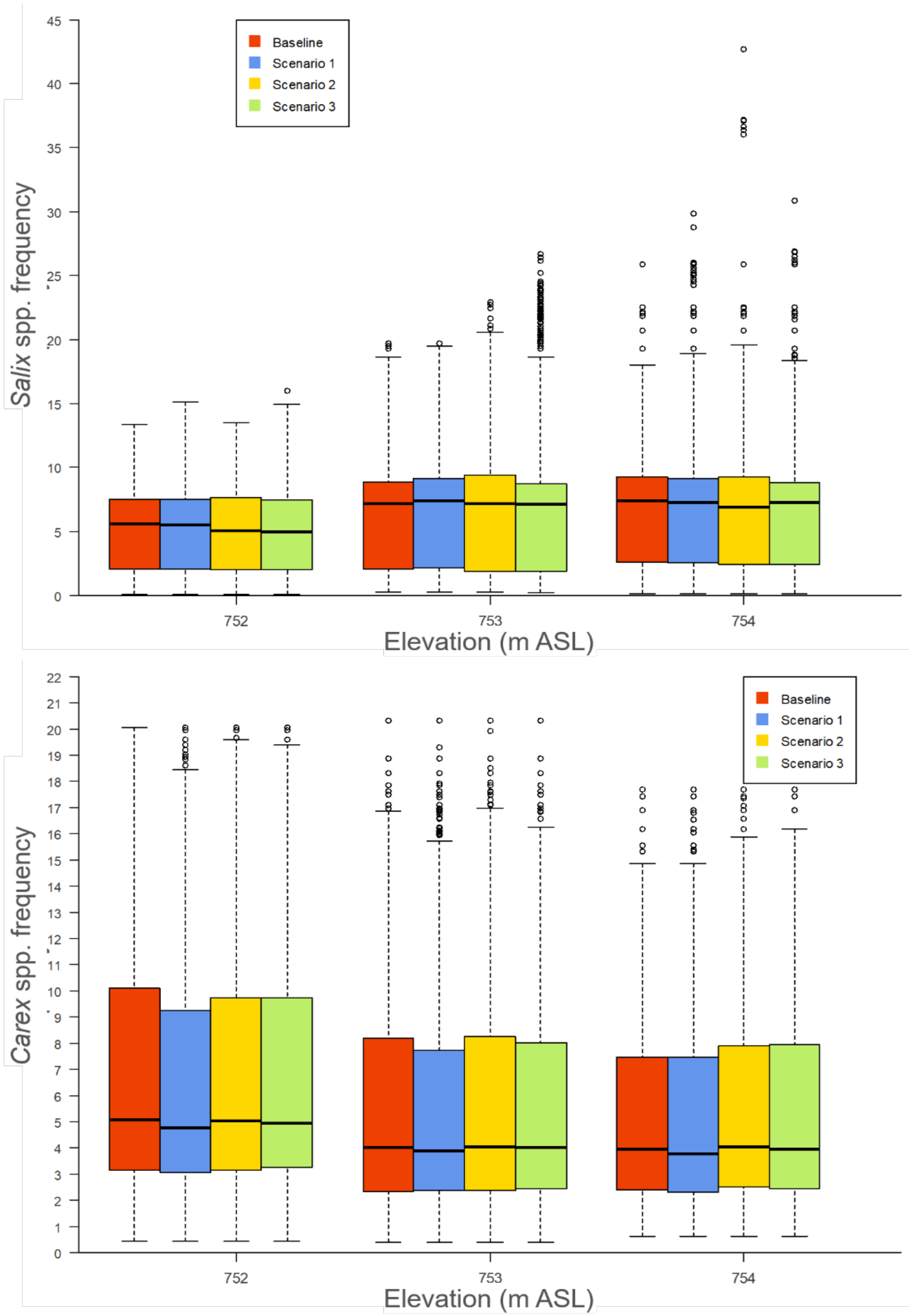


Figure 9-9: Variation in predicted frequency of occurrence of *Carex* spp. (bottom panel) and *Salix* spp. (top panel) under baseline conditions and three scenarios of increased (+60 cm) reservoir elevations over 1000 simulations per elevation band. See Methods for scenario descriptions.

Polygons (Landscape)

Table 9-4: 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 2018 compared to 2007, and '↑' indicates an increase in spatial extent in 2018 as compared to 2007. Combinations of symbols provide an indication of changes in extent of cover within each landscape unit over time.

Landscape Unit	Year						Change in area (ha) between 2018 and...					Per cent change between 2018 and ...					Direction
	2007	2010	2012	2014	2016	2018	2007	2010	2012	2014	2016	2007	2010	2012	2014	2016	
Beaver Mouth	31.1	26.3	26.2	26.1	25.6	25.1	-6.0	-1.2	-1.1	-1.0	-0.5	-19.3	-4.6	-4.2	-3.9	-1.9	↓; =
Succour Creek	--	121.4	121.6	128.1	128.2	125.2	--	3.8	3.6	-2.9	-3.0	--	3.2	3.0	-2.2	-2.3	=
Bear Island	391.3	408.8	408.6	439.4	438.9	438.2	47.0	29.4	29.7	-1.1	-0.7	12.0	7.2	7.3	-0.3	-0.2	↑; =
KM 79	135.5	123.7	126.3	131.1	131.0	131.3	-4.1	7.6	5.0	0.2	0.3	-3.1	6.2	4.0	0.2	0.3	=
Bush Arm	523.6	466.3	463.1	463.8	459.1	485.9	-37.7	19.6	22.7	22.0	26.7	-7.2	4.2	4.9	4.7	5.8	=
Sullivan Arm	8.2	1.8	1.8	1.7	1.7	2.8	-5.4	1.0	1.1	1.1	1.1	-65.6	57.4	60.9	65.5	65.5	↓; ↑
Sprague Bay	--	33.1	33.1	35.1	33.7	35.3	--	2.2	2.2	0.2	1.6	--	6.6	6.6	0.6	4.6	=
Encampment Creek	75.2	71.1	71.3	74.7	73.1	73.2	-2.0	2.1	1.9	-1.5	0.1	-2.6	2.9	2.7	-2.0	0.2	=
Howard Creek	9.0	10.8	10.8	11.1	10.9	11.0	2.0	0.2	0.2	-0.1	0.1	22.5	2.1	2.1	-1.0	0.8	↑; =
Hugh Alan Bay	35.8	37.4	37.0	40.9	40.9	41.4	5.6	4.0	4.4	0.5	0.5	15.5	10.8	11.8	1.1	1.1	↑; =
Windfall Creek	38.4	12.5	13.0	15.2	14.9	18.4	-20.0	6.0	5.4	3.2	3.5	-52.0	47.9	42.0	20.8	23.2	↓; ↑
Grouse Creek	45.1	12.3	12.5	13.5	13.0	13.6	-31.5	1.3	1.1	0.1	0.6	-69.9	10.6	8.8	0.8	4.6	↓; ↑; =
Mount Blackman	14.9	4.1	4.2	5.1	5.1	5.2	-9.7	1.0	1.0	0.0	0.0	-65.3	24.8	22.7	0.8	0.8	↓; ↑; =
Ptarmigan Creek	20.7	16.3	16.4	15.8	15.8	15.9	-4.7	-0.4	-0.4	0.1	0.1	-22.8	-2.2	-2.5	0.6	0.6	↓; =
Yellow Jacket	47.1	33.5	33.3	35.5	34.3	34.3	-12.8	0.7	1.0	-1.3	-0.1	-27.2	2.2	2.9	-3.6	-0.3	↓; =
Canoe Reach	645.4	660.6	662.1	739.9	740.8	742.0	96.6	81.3	79.9	2.0	1.2	15.0	12.3	12.1	0.3	0.2	↑; =
Total	2021.1	2040.1	2041.1	2177.3	2167.3	2198.8	177.7	158.8	157.7	21.5	31.5	8.8	7.8	7.7	1.0	1.5	=

Table 9-5: Spatial extent of vegetation (hectares) sampled from aerial photography in each vegetation community (VCC) since 2007. '=' indicates no or very minor (< 10 per cent) change, '↓' indicates a decline in spatial extent in 2018 compared to 2007, and '↑' indicates an increase in spatial extent in 2018 as compared to 2007. Combinations of symbols provide an indication of changes in extent of cover within each community over time. See Table 4-2 for VCC definitions.

VCC	Year						Change in area (ha) between 2018 and...					Per cent change between 2018 and ...					Direction
	2007	2010	2012	2014	2016	2018	2007	2010	2012	2014	2016	2007	2010	2012	2014	2016	
LL	537.3	621.5	615.6	612.6	622.9	639.9	102.6	18.4	24.3	27.3	17.0	19.1	3.0	3.9	4.5	2.7	↑; =
CH	336.9	279.9	282.5	283.4	270.8	280.0	-56.9	0.2	-2.5	-3.3	9.3	-16.9	0.1	-0.9	-1.2	3.4	↓; =
TP	88.6	225.7	223.8	248.6	249.0	251.1	162.5	25.4	27.2	2.5	2.1	183.4	11.2	12.2	1.0	0.8	↑; =
MA	102.6	105.7	105.9	105.9	105.7	102.4	-0.2	-3.3	-3.5	-3.5	-3.3	-0.2	-3.1	-3.3	-3.3	-3.1	=
KS	226.6	210.2	215.7	215.3	207.2	219.5	-7.1	9.3	3.8	4.2	12.3	-3.1	4.4	1.8	2.0	6.0	=
BR	16.7	41.5	40.7	40.9	39.5	36.0	19.3	-5.5	-4.7	-4.9	-3.4	115.1	-13.2	-11.5	-12.0	-8.7	↑; ↓; =
RC	9.4	31.5	28.0	25.4	27.8	22.7	13.4	-8.7	-5.2	-2.6	-5.0	142.6	-27.7	-18.7	-10.4	-18.1	↑; ↓
RD	--	0.63	0.63	0.57	0.57	0.57	--	-0.06	-0.06	0.00	0.00	--	-10.0	-10.0	0.0	0.0	↓; =
CO	169.7	146.1	132.7	128.5	139.6	129.7	-40.0	-16.4	-3.0	1.2	-9.9	-23.6	-11.2	-2.3	0.9	-7.1	↓; =
WB	4.4	128.8	129.7	143.9	142.9	146.9	142.4	18.0	17.1	3.0	3.9	3204.2	14.0	13.2	2.1	2.7	↑; =
SH	145.7	52.4	55.0	43.3	44.6	42.7	-103.1	-9.7	-12.4	-0.6	-1.9	-70.7	-18.5	-22.4	-1.3	-4.3	↓; =
BS	9.3	12.0	10.7	10.9	11.2	11.2	1.9	-0.8	0.5	0.3	0.0	20.6	-6.7	4.9	2.6	0.3	↑; =
WS	36.8	34.1	31.8	34.2	46.3	44.1	7.3	10.0	12.3	9.9	-2.2	19.9	29.2	38.6	28.9	-4.8	↑; =
CT	48.2	20.8	19.2	16.1	25.8	29.0	-19.2	8.2	9.8	12.9	3.3	-39.8	39.4	51.0	80.4	12.6	↓; ↑
LH	4.3	0.50	0.50	0.52	0.52	0.52	-3.83	0.02	0.02	0.00	0.00	-88.0	4.5	4.5	0.0	0.0	↓; =
MC	23.4	0.19	0.15	0.07	0.07	0.12	-23.23	-0.07	-0.03	0.05	0.05	-99.5	-34.9	-18.0	77.7	77.7	↓; ↑
DR	26.8	37.0	50.1	61.1	47.3	48.7	21.9	11.8	-1.4	-12.4	1.4	81.8	31.9	-2.8	-20.2	3.0	↑; ↓; =
FO	25.0	22.2	19.6	61.1	58.1	58.1	33.1	35.9	38.5	-3.0	0.0	132.5	161.9	196.2	-4.8	0.1	↑; =
WD	209.3	69.4	78.6	55.8	55.8	60.4	-148.8	-9.0	-18.2	4.7	4.7	-71.1	-13.0	-23.2	8.4	8.4	↓; =
DI	--	--	--	22.3	28.4	31.1	--	--	--	8.8	2.7	--	--	--	39.5	9.4	↑; =
SW	--	--	--	67.1	43.5	44.1	--	--	--	-23.0	0.6	--	--	--	-34.3	1.4	↓; =
Total	2021.1	2040.1	2041.1	2177.3	2167.3	2198.8	177.7	158.8	157.7	21.5	31.5	8.8	7.8	7.7	1.0	1.5	=

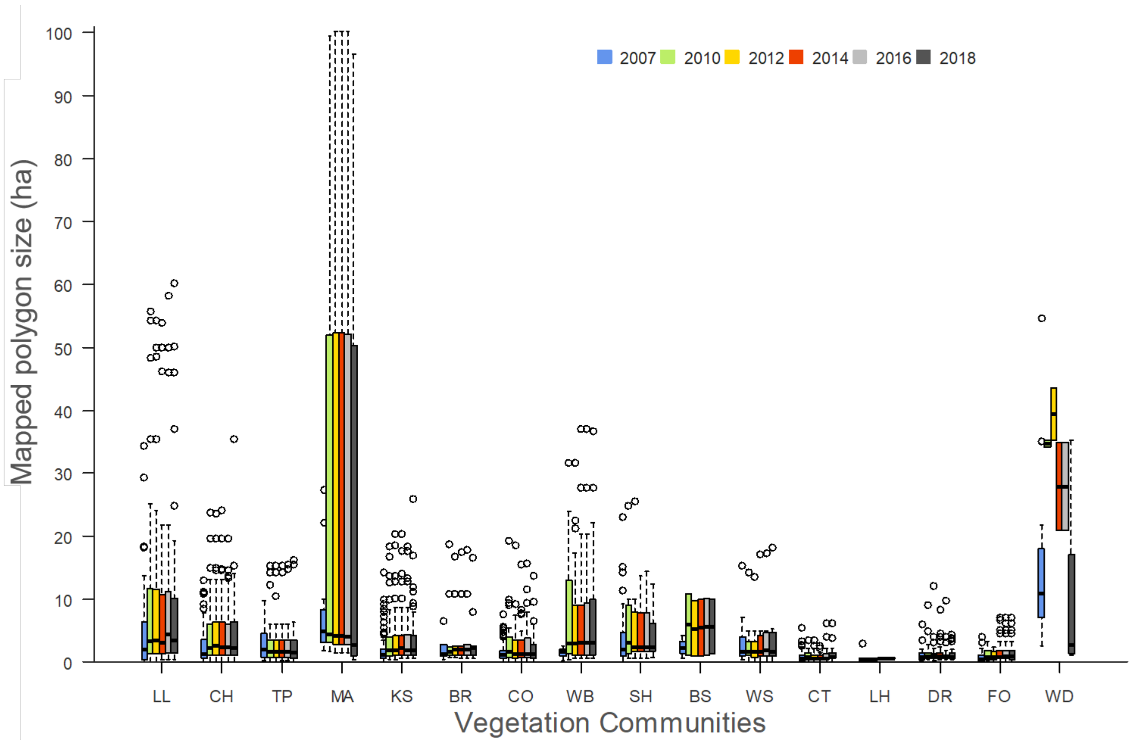


Figure 9-10: **Variation in the size (ha) of mapped polygons over time across the different vegetation communities in Kinbasket Reservoir.** Vegetation community codes are expanded in Table 4-2.

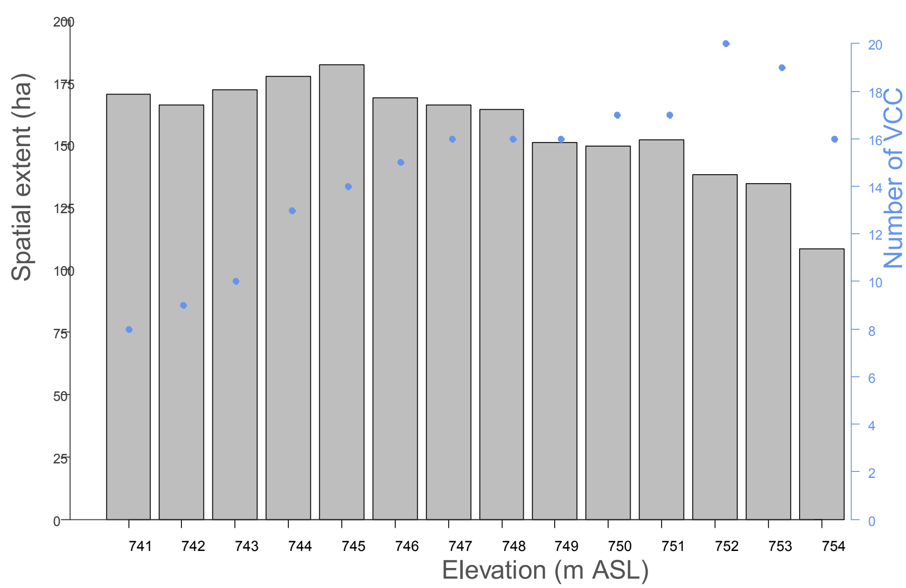


Figure 9-11: Total spatial extent (left axis) and number of vegetation communities (right axis, in blue) per elevation band in 2018.

9.2 Annual Sampling Summaries

9.2.1 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 4-2). 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.

9.2.2 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 wood debris removal program.
- When a given VCC 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.

9.2.3 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.

9.2.4 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.

9.2.5 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. 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.

9.2.6 Year 10 – 2016

Field sampling in 2016 followed the methods used in previous years. A total of 73 transects were sampled representing 13 vegetation communities and 12 landscape units. Aerial photos were captured digitally in 2016 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 2016. The spatial extent of mapped vegetation communities differed significantly from 2007, but not from 2014. Differences between 2007 and 2016 were attributed in part to mapping errors made in 2007 and refinements to the vegetation polygons in subsequent years.