Peace Project Water Use Plan

Williston Recreation Use

Implementation Year 10

Reference: GMSMON-20

BC Hydro Williston Reservoir Recreation Use Monitoring Program

Final Draft

Study Period: 2009-2018

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Note to Readers:
This report has been edited, by BC Hydro, from the author's original version independent of discussion with Synergy Applied Ecology who were no longer available. The data were not re-analyzed as part of the editing process, nor were their conclusions altered. Accordingly, the report will remain in draft form.

The intent of these revisions is to improve the readability and clarification of facts (e.g., reservoir elevations), and are in green text.

Our reviewer noted the following themes of concern that remain unresolved without further discussion with Synergy Applied Ecology, who are no longer available.

- Use of Elizabeth Creek as a control site since access to this ramp was restricted and may have created an additional barrier to users.
- Addition of campsites at the control locations may have warranted more analyses.
- Concern about use of #boat-visits for control sites, vs # of boats launched at upgraded sites.
- Lack of adequate pre-construction data at some sites.

An addendum to the report reflecting on the above concerns has been prepared by the report reviewer and is included at the end of this draft report.

GMSMON-20 WILLISTON RESERVOIR RECREATION USE MONITORING PROGRAM FINAL REPORT, 2009 – 2018

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Reference: Peace River Water Use Plan; BC Hydro Project Q8-8964 Williston Reservoir Recreation Use; BC Hydro GMSMON-20; BC Hydro CO 93595; SAE SPN39.

EXECUTIVE SUMMARY

Improving boater access to the Williston Reservoir **at selected sites** during all ice-free operating elevations is a requirement of BC Hydro's Peace Region Water Use Plans. BC Hydro committed to improving existing facilities and constructing new boat launches at existing recreation sites along the reservoir to comply with this obligation. A 10-year reservoir recreation use monitoring program was initiated in 2009 to assess use of boat launch sites, before and after improvements. To determine whether physical works to boat launches at Dunlevy and Mackenzie Recreation Sites improved boater access between May 14 and October 31, vehicle counters and remote cameras were used concurrently to evaluate 2 primary management objectives: Does recreational use of Williston Reservoir boat launches increase after boat access is improved? What is the frequency of use of newly constructed boat launches?

The 10-year (2009 – 2018) monitoring program followed a before-after-control-impact study design to evaluate changes in recreational use of 6 sites that provide boat access to Williston Reservoir. Two of the sites (Dunlevy and Alexander Mackenzie) had boat ramp improvements during the monitoring period, two sites (Cut Thumb and Six Mile) had campground improvements, independent of the Water Use Plan and two sites with no improvements (Elizabeth Creek and Finlay Bay) were monitored as controls.

We used generalized linear mixed-effects multiple regressions for count data to analyze whether the number and timing of boat visits changed as a result of boat ramp improvements. The design was a before-after-impact-control assessment of daily site visits, with monitoring over 171 consecutive days (May 14 – October 31) annually for 10 years (2009 – 2018). Treatments included boat ramp improvements at 2 sites, campground improvements at 2 sites, and no improvements at 2 sites designated as controls. Treatment years and boat access varied among sites, therefore changes in site visits after treatments were analyzed independently for each site.

At Dunlevy, boat ramp improvements in 2014 resulted in a significant increase in daily boat counts, with the largest increases during lower reservoir elevations early in the year. No significant increases in site use were observed at Mackenzie Landing following boat ramp improvements in 2014.

Primary assumption underlying boat ramp improvements was that reservoir access was limited at low water levels. Reservoir elevation was a limiting factor at Dunlevy, but not Mackenzie Landing.

Observed changes in boat visits at Dunlevy demonstrate the desired positive impact that ramp upgrade investments made in achieving the management goals.

GMSMON-20 STATUS of OBJECTIVES, MANAGEMENT QUESTIONS, and HYPOTHESES after Year 10.

Objectives	Management Questions	Management Hypotheses	Year 10 (2018) Status
Conduct a reservoir recreation use survey to determine if recreational activity on Williston Reservoir increases in response to greater boat access opportunities that result from construction of new boat launches and modification of existing boat launches.	1) Does the recreational use of the Williston Reservoir boat ramps increase after boat access has been improved?	H1: Recreational use of boat ramps has increased following improvements to boat access.	Recreational use (using boat-visits as a proxy) increased at **Dunlevy** in response to greater boat access opportunities provided by ramp improvements. There was no change in recreational use (using boat-visits as a proxy) at **Mackenzie Landing** in response to boat ramp improvements. *see addendum
	2) What is the frequency of use of newly constructed boat ramps?	H2: Timing (e.g., by month) of boating parties for recreational activities changes following improvements to boat access.	Peak boat visits at **Dunlevy** shifted from mid-season (Day 80; August 1st) before ramp improvements to early season (<Day 50; May 14 – July 1) after improvements. There was no significant difference in the timing of peak boat visits at **Mackenzie Landing** before and after ramp improvements

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INTRODUCTION

BC Hydro Water License Requirements

Improving boat access to Williston Reservoir at selected sites during the boating recreation season is a requirement of BC Hydro Peace Region Water Use Plan. Generally, boat access to the reservoir is limited at low water levels except where boat ramps provide low-water access. BC Hydro committed to improving existing facilities and constructing new boat ramps at existing recreation sites along the reservoir to comply with this obligation, as part of the Peace Water Use Plan (BC Hydro 2008).

Monitoring Program

BC Hydro Project GMSMON-20 (Williston Recreation Use Terms of Reference, including Addendum 1) was a 10-year (2009 – 2018) monitoring program based on a before-after-control-impact study design to evaluate recreational use of 6 sites that provide boat access to Williston Reservoir.

During the monitoring period, two BC Hydro boat ramps were reconstructed to improve access at low reservoir water levels, two recreation sites were coincidentally expanded by third parties to increase camp site capacity, and two sites were unaltered and monitored as controls for statistical analysis of changes in site use. Access to the control site was altered part way through the study period. Vehicle counters and motion-sensitive cameras were used concurrently to collect daily site use data from May 14 – October 31 annually.

Management Questions

The monitoring program was established to address two ~~primary~~ management questions (BC Hydro 2008):

1. Does recreational use of Williston Reservoir boat launches increase after boat access is improved?
2. What is the timing and frequency of use of newly constructed boat launches? Specifically, does seasonal use change with improved access to new areas of the reservoir, and improved access during low reservoir levels?

This report summarizes the results of the 10 year monitoring program, and provides statistical analysis of changes in the number, timing, and frequency of boat visits to recreation sites that provide access to Williston Reservoir.

STUDY AREA

Williston Reservoir

The Williston Reservoir is the largest man-made, hydroelectric reservoir in British Columbia with a surface area of 1,779 km^2 and a shoreline perimeter of 1,700 km (**Figure 1**). The maximum licensed water elevation is 672 masl and a minimum elevation of 640 masl. The watershed is the confluence of 3 rivers which define the reaches of the reservoir: the Finlay Reach (north), Parsnip Reach (south) and Peace Reach (east). Primary access to the Peace Reach is via the community of Hudson's Hope. Primary access to the Parsnip and Finlay Reaches is via the community of Mackenzie.

The reservoir offers considerable recreational, fishing, hunting and wildlife viewing opportunities as boaters can access remote areas of the watershed. Recreational boating on Williston Reservoir occurs predominantly from May through October, which comprises the majority of the ice and snow-free periods annually. Generally, boat access to the reservoir is limited at low water levels except where boat ramps are designed to provide low-water access.

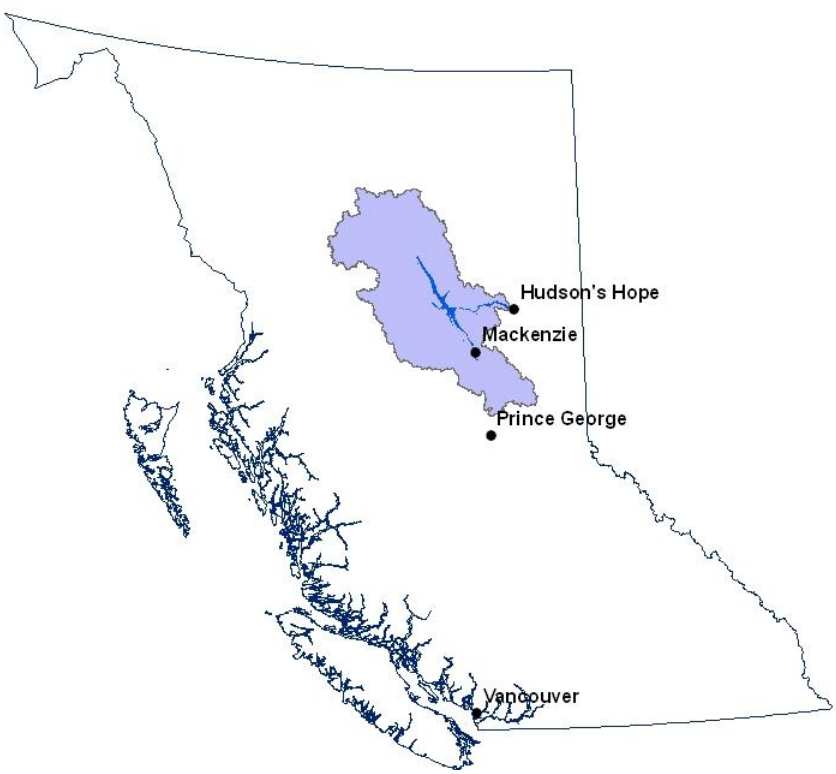


Figure 1. The Williston Reservoir and surrounding watershed boundary in northern British Columbia.

Gateway Communities

Hudson's Hope (Peace Reach)

The municipality of Hudson's Hope is the access point for Williston Reservoir Peace Reach recreation sites that were monitored during this study. The community is at the junction of Highways 97 and 29, and is the gateway for traffic from northeast BC and northern Alberta via Fort St John (approx. 21,000 residents) and central BC via Chetwynd (approx. 2,685 residents). Hudson's Hope is primarily a rural and agricultural community with BC Hydro serving as its primary employer. The W.A.C. Bennett and Peace Canyon hydroelectric dams are located on the Peace River, adjacent to the community. Hudson's Hope had approximately 1,000 year-round residents during the monitoring program.

Mackenzie (Parsnip Reach)

The municipality of Mackenzie BC is the access point for Williston Reservoir Parsnip Reach recreation sites that were monitored during this study. The community is 30 km from the junction of Highways 97 and 39, and is the gateway for traffic from central BC via Prince George (approx. 78,675 residents), 180 km south of Mackenzie. Mackenzie is a resource-based community with forestry operations serving as the primary employer. There were approximately 3,800 year-round residents during the monitoring program.

Recreation Site Selection

Six recreation sites that offer boat access to the Williston Reservoir were included in the monitoring program (BC Hydro 2008). Two sites were along Williston Reservoir's Peace Reach: Dunlevy and Elizabeth Creek. Four sites were along the Parsnip Reach: Finlay Bay (76 Mile), Six Mile Bay (43 Mile), Cut Thumb Bay (38 Mile), and Alexander Mackenzie Landing (22 Mile) (**Figure 2**). Boat launch condition and facilities varied among the sites during the monitoring period (**Table 1).**

These ~~6~~ six recreation sites are the primary boat access to Williston Reservoir in the Peace and Parsnip Reaches. Other nearby Williston Reservoir boat access points were limited to a small private marina on 12 Mile Rd at Hudson's Hope in the Peace Reach, and limited access at ~~2~~ two unmaintained sites in the Parsnip Reach (Weston Recreation Site and Strandberg log dump).

Table 1. Condition of boat ramps at Williston Reservoir recreation sites monitored between 2009 - 2018.

Site	Description
Cut Thumb	No formal boat ramp but suitable for boat access at most water levels. **Campground improved in 2013.**
Six Mile Bay	Constructed gravel boat launch suitable for use at mid to high water levels (late season) only. Small boats can be walked in at low water levels. **Campground improved in 2015.**
Finlay Bay	Constructed gravel boat launch suitable for use at most water levels.
Elizabeth Creek	Constructed concrete boat launch suitable for most water levels.
Dunlevy	Constructed concrete boat launch suitable for high water levels only in 2009 -2013. **Boat ramp improved in 2014** to enable reservoir access at ≥660.5 masl**.**
Mackenzie Landing	Constructed concrete boat launch suitable for use at most water levels, with toe of primary high water ramp at ≥662 masl. Added to the monitoring program in 2011. Rudimentary road used to access reservoir at low water levels in 2011 - 2013. **Low water boat ramp improved in 2014** to enable reservoir access at ≥658 masl**.**

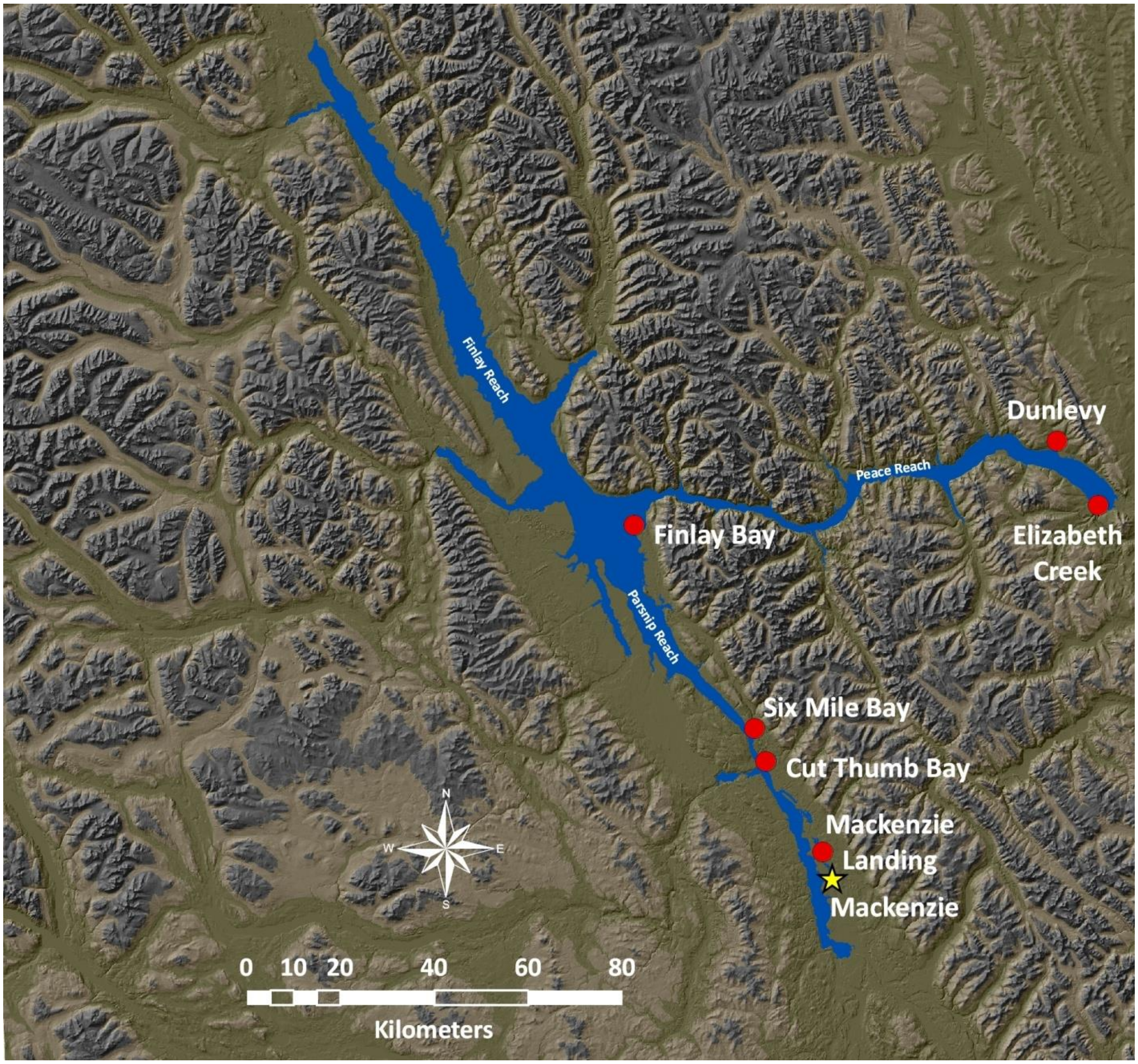


Figure 2. Williston Reservoir recreation sites included in the GMSMON20 monitoring program, 2009 - 2018.

Recreation Site Descriptions

Peace Reach

Dunlevy – Improved Boat Ramp

ACCESS: Dunlevy recreation site is approximately 40 minutes driving time from Hudson's Hope. Access is from Hudson's Hope via Highway 29, turning north on 12 Mile Road and following this well-maintained rural gravel road for 26 kms to the site.

SITE DESCRIPTION: This site has a concrete boat ramp with a large open area for parking and 2 outhouses. ~~(Photos in Appendix A)~~. Although the site is intended as a day use site, there was evidence that the site is used for overnight camping. This site is part of Butler Ridge Provincial Park.

SITE IMPROVEMENTS DURING THE STUDY PERIOD – **Boat Ramp Improved**. In 2009 (Year 1), the boat ramp was a 6 m wide concrete ramp and was designed to provided reservoir access at 663.2 masl (toe elevation of 662 masl). The boat ramp was not usable during low reservoir elevation due to a steep sandy drop-off ~~(Appendix A)~~. As well, the ramp was in disrepair, as the concrete slabs on one side had collapsed due to shoreline erosion, rendering only one side (3 m wide) of the ramp usable. Use of the boat ramp when elevation was less than 667 masl was difficult.

In May 2013 (Year 5) the concrete slabs that were undermined by shoreline erosion were removed, reducing the existing ramp to 3 m in width. Safety barriers were installed, and the shoreline slope stabilized with rip rap material. These improvements did not extend the ramp to early season water elevation; launching in May and June when elevation was less than 667 masl remained difficult. ~~(Appendix A)~~.

The Dunlevy boat ramp was re-constructed by BC Hydro in 2014 (Year 6). The design (GMSWORKS 54 Moffat and Nichols 2013) was to 660 m to toe of concrete ramp with an allowance to 658 m with rip rap. Due to the extent of construction, the site was closed to the public in 2014, and therefore not monitored that year. Improvements to the ramp, the approach, and the parking lot were finished in the spring of 2015 (Year 7). The site was re-opened to the public on May 15, 2015. The ramp grade was reduced, and the ramp is now approximately 6 m wide with room for vehicles with boat trailers to turn around at the top of the launch. The toe of the ramp reaches to 660.~~5~~9 masl, extending the ramp's utility at lower reservoir elevations ~~(Appendix A)~~.

Elizabeth Creek – No Improvements

ACCESS: Elizabeth Creek recreation site is approximately 20 minutes driving time from Hudson's Hope. Access is via paved Highway 29, turning right (north) approximately 300 m after crossing the crest of the WAC Bennett Dam.

DESCRIPTION: This site has a concrete boat ramp approximately 6 m wide and in good condition ~~(Appendix A)~~. The ramp was constructed to allow all sizes of boats to access the reservoir at both low and high water elevations. There are two outhouses on site and a gravel parking lot with area for vehicles with boat trailers. The site is intended for day-use, as there are no defined camping areas, but overnight parking is common.

SITE IMPROVEMENTS DURING THE STUDY PERIOD – **No Improvements**. Elizabeth Creek was designated as a Peace Reach control site for the monitoring program.

NOTES: Temporary access closures during periods of extensive construction for scaling on the WAC Bennett dam spillway (Years 2011 and 2012), spilling at the dam due to high reservoir elevation (Year 2012), and paving of the Dam Crest Road (Year 2017). Since 2011 (Year 4), access to Elizabeth Creek across the dam required passing through a security check point with personal identification required.

Parsnip Reach

Alexander Mackenzie Landing (12 Mile) – Improved Boat Ramp

ACCESS Alexander Mackenzie Landing recreation site is located approximately 10 minutes driving time from Mackenzie. Access is via the Parsnip West FSR for approximately 7 km with several signs that lead users to the site from Highway 39. This recreation site is known to long-time Mackenzie residents as the 12 Mile Recreation Site.

DESCRIPTION This site has a concrete boat ramp approximately 6 m wide and in good condition. The site is well-maintained and designated for day use with a picnic area, cooking shelter and outdoor amphitheater. There is parking with ~~2~~ two outhouses on site. Immediately adjacent to the day use site is the BC Hydro Alexander Mackenzie Landing campsite which contains 10 camp stalls suitable for all RVs. A foot path joins the two sites. This site was added to the monitoring program in 2011 (Monitoring Year 3 was the first monitoring year for this site).

SITE IMPROVEMENTS DURING THE STUDY PERIOD – **Boat Ramp Improved.** In 2009, the primary boat ramp was in good condition (**Appendix A**). Users launched boats directly from the concrete ramp at high reservoir elevations of 665 masl or above but had to drive down the foreshore area on a rudimentary, gravel road to access the reservoir at low elevation. Improvements to the Mackenzie Landing boat ramp were undertaken by BC Hydro in 2014 (Year 6) to increase boater use at low reservoir elevation (REF **GMSWORKS-47; Boehringer 2014).** Users launch directly from the upper ramp at elevation 66~~5~~2 masl or above. At lower elevations, users drive down the foreshore area on a newly constructed, gravel road to access the reservoir using a secondary low elevation concrete boat ramp that extends to 658 masl. As the reservoir elevation increases the low elevation launch is submerged. Buoys mark the underwater road to boaters ~~(**Appendix A**)~~. The parking lot was expanded in 2013 (Year 5) to provide designated parking for vehicles with boat trailers.

NOTES Heavy rain in May 2011 (Year 3) caused damage to the Mackenzie Landing access road. Access to the boat ramp and picnic area remained open to the public while heavy equipment made temporary repairs. Permanent repairs to the access road and stabilization of an eroding bank adjacent to the parking lot were completed in June – August 2011. The site was closed in June for road repair but was open for the remainder of the year.

Cut Thumb Bay (38 Mile) – Improved Campground

ACCESS Cut Thumb Bay recreation site is located approximately 35-40 minutes driving time from Mackenzie. Access is via the Parsnip West Forest Service Road (FSR), a well-maintained, radio-assisted gravel mainline, turning west between the 33 and 34 km markers onto a 4 km long gravel spur road. This recreation site is known to long-time Mackenzie residents as the 38 Mile Recreation Site.

DESCRIPTION This recreation site is designated for day use and overnight camping. There is no formal boat launch at this site, however, during low reservoir elevation there is a large gravel bar where users can park, camp, and launch boats ~~(**Appendix A**)~~. The narrow road that leads to the gravel bar becomes the boat launch at highest water elevation. The reservoir water elevation dictates how much room users have to launch boats and camp at this site. When reservoir elevation is low there is more room for parking and camping but decreases as water elevation increases.

SITE IMPROVEMENTS DURING THE STUDY PERIOD – **Campground Improved** In 2009 (Year 1) there were 9 designated camp sites with picnic tables, and 3 outhouses. The number of campsites at Cut Thumb Bay was expanded in 2013 (Year 5) as a voluntary community service by Duz Cho Logging and Duz Cho Construction. Fourteen new sites were cleared and graveled. Four new outhouses were built as well. No improvements were made to the boat launch areas but woody debris that accumulated at the ~~2~~ two launching sites due to high reservoir elevation in 2012 were removed by Duz Cho.

NOTEWORTHY EVENTS Duz Cho hosts a popular community fishing derby at Cut Thumb recreation site in late August annually.

Six Mile Bay (43 Mile) – Improved Campground

ACCESS Six Mile Bay recreation site is located approximately 45-50 minutes driving time from Mackenzie. Access is via the Parsnip West FSR, turning west at the 41 km marker onto an approximately 1 km long, dirt access road.

DESCRIPTION This recreation site is designated for day use and overnight camping. At low reservoir elevation, an open, gravel area provides additional parking or camping space. Access to this gravel bar is via the dirt road that also serves as the boat launch. At elevations lower than 667 masl, it may be difficult to launch larger boats as there is a steep drop off to the water and the sandy substrate may cause vehicles to become stuck ~~(**Appendix A**)~~.

SITE IMPROVEMENTS DURING THE STUDY PERIOD – **Campground Improved** In 2009 (Year 1) the site consisted of ~~1~~ one camp site with picnic table and outhouse. When the one camp spot was taken during high water elevation, it limited parking and constrained the amount of room that visitors had to maneuver vehicles and trailers down the access road, potentially deterring use of the boat launch. Seventeen new camp sites were established at Six Mile Bay in August 2015 (Year 7) by the District of Mackenzie, McLeod Lake Indian Band, and Recreation Sites and Trails Branch Forests, Lands and Natural Resource Operations. An open, gravel area adjacent to the boat launch now provides additional boat trailer or day parking space. No improvements were made to the boat ramp and boat access when reservoir elevation is less than 667 masl remains difficult.

~~NOTES~~

Finlay Bay – No Improvements

ACCESS Finlay Bay recreation site is approximately 1.5-2 hours driving time from Mackenzie. Access is via the Parsnip West FSR. At the 96 km marker, the Parsnip terminates and there is a turn off onto a 1 km long, narrow (approx. 4 m wide) gravel road leading to the recreation site.

DESCRIPTION The site consisted of 11 camp sites with picnic tables, and 3 outhouses. There is also a large open field area where many users prefer to camp and where boat trailers are parked. The boat launch is a short gravel road that is approximately 4 m wide ~~(**Appendix A**)~~. There are remnants of old slabs of concrete and pieces of rebar laying off to the side, indicating that a concrete launch once existed. At low reservoir elevation, vehicles must drive over rocks and sand to reach the water.

SITE IMPROVEMENTS DURING THE STUDY PERIOD – No Improvements Finlay Bay was not improved and was designated as a Parsnip Reach control site for the monitoring program.

Site Closures and Special Events

Over the course of the GMSMON-20 monitoring program, site closures (e.g., during construction periods) and special events were noted as potential influences on levels of recreation site use. ~~**APPENDIX B** provides a summary of events for consideration in data analyses and interpretation~~. Year 3 (2011) was an anomalous weather year. A rain-soaked spring in 2011 caused local flooding, which led to several washouts and road closures in the region, including along the Parsnip West FSR.

METHODS

Study Design

The 10-year (2009 – 2018) monitoring program followed a before-after-control-impact study design to evaluate changes in recreational use of 6 sites that provide boat access to Williston Reservoir. Two of the sites (Dunlevy and Alexander Mackenzie) had boat ramp improvements during the monitoring period, two sites (Cut Thumb and Six Mile) had campground improvements, and two sites with no improvements (Elizabeth Creek and Finlay Bay) were monitored as controls. Access to Elizabeth Creek was altered part way through the study period.

Time-synchronized vehicle counters and motion-sensitive cameras were used concurrently to record daily site use counts from May 14 through October 31 (171 monitoring days) annually, when most recreational boating occurs on Williston Reservoir. Vehicle counters provided total site use counts, while photo-validated counts provided data on the number of visitors bringing boats to each site.

Similar assessment of trends at the ~~2~~ two sites with campground improvements, and ~~2~~ two sites with no improvements, provided a reference for whether or not changes in daily boat visits at Dunlevy and Mackenzie ~~can~~ could be attributed to boat ramp improvements or resulted from other unmeasured variables.

Photo-validated site use counts also provided an opportunity to evaluate additional site use characteristics of management interest. We identified the minimum number of repeat visitors at each site as an index of ~~(~~user satisfaction~~)~~. We also reported on the number of boat visits as a percentage of total site visits and compared duration of stay for the two user groups. We summarized time spent on the boat launch, as an index of site capacity.

Data Collection

Site Use Data - Deployment and Management of Monitoring Equipment

Traffic Counters

We installed Generation III (G3) vehicle counters manufactured by TRAFx Research Ltd., Canmore Alberta, pre-programmed to VEH-4d mode. The counters employ magnetometers that are capable of operating in temperature ranges of -40°C to 50°C with an expected battery life of approximately 7 - 14 months and enough storage to accommodate up to 14,000 data records. All counters were deployed with the same settings annually to ensure consistency in data interpretations among sites and years

(**Table 2**). Counters were placed in waterproof, moisture controlled cases roadside at each site as per manufacturer's specifications, such that it would detect vehicle traffic traveling in both directions.

Because access and boat launch layouts differed among sites, we placed the monitoring equipment along the access roads into each site, except at Elizabeth Creek and Mackenzie Landing, in order to keep data capture consistent between sites, among years and, after launch improvements. At Elizabeth Creek and Mackenzie Landing, remote monitoring equipment was installed directly adjacent to the constructed, concrete boat launch.

Table 2. Vehicle counter settings during the 10-year (2009 - 2018) monitoring program.

Parameter	Setting Code	Setting
Period	000	
Delay	024	6 second delay
Threshold	012	
Rate	Slow	

Cameras

We installed ScoutGuard SG550 digital cameras in 2009 – 2013 and replaced them with Browning Special Ops XTR digital cameras in 2014 - 2018. Both incorporate a passive infra-red motion sensor and an indetectable flash in darkness. All photos were stored on 2GB SD memory cards, allowing for over 2000 photos at 3MP resolution. The cameras operate in temperatures ranging from -20°C to 60°C and humidity of 5-90%. All cameras were programmed with the same settings annually (**Table 3**), and time-synchronized to match the vehicle counter settings. The cameras were installed in areas where the risk of detection was minimal and where the photo contained both the vehicle counter location and the largest field of view possible. Equipment was concealed to reduce the likelihood of changes in site user behavior reacting to the presence of monitoring equipment, and to lower the probability of theft or vandalism. No personal site user information was collected as this was not relevant to our analysis.

Since Year 2 (2010), cameras were installed in steel lock boxes to discourage camera theft. In the event camera set-ups were discovered, lock boxes were labeled with a brief project description and a contact phone number for more information.

Table 3. Remote camera settings during the 10-year (2009 - 2018) monitoring program.

Parameter	Setting
Mode	Camera
No. photos per event	1
Photo quality (MP)	3
Delay (sec.)	0
Sensitivity	High
Time stamp	On
Timer	Off

Reservoir Elevation and Weather Data

Williston Reservoir elevation data were obtained post-hoc from BC Hydro. Weather data were obtained post-hoc from Environment Canada weather station databases for Mackenzie (MackA) and Fort St John (FSJA).

Data Processing

Integrating Counter and Camera Data

Data from the vehicle counters and cameras were downloaded in the field approximately every 6 weeks during the annual monitoring period. Vehicle counter and remote camera data, cross-referenced by event date and time stamps, were imported to an MS Access database.

Vehicle counter events (each detection of a metallic object passing the counter) formed the basis of the complete dataset. Counter data were validated by photo interpretation to determine arrival and departure times of individual vehicles, the presence of a boat or boat trailer, and the direction of the vehicle (arriving at the site or departing). We assigned unique user vehicle IDs for each site visit, enabling an estimate of the minimum number of users who visited each site annually, the proportion of site users with boats, the duration of stay, and whether they were a repeat visitor.

Site visits were defined by the first and last observation of the vehicle (with boat or RV trailer, if applicable) for each discrete visit to a site. For example, a vehicle arriving and leaving on Day 1 and returning again on Day 2 constituted two independent site visits. A vehicle arriving with a boat or RV trailer on Day 1, leaving and returning multiple times without the boat or RV trailer, and finally exiting with the boat or RV trailer on a later date, was recorded as one site visit. In all cases, only one~~1~~ photo (arrival or exit) was required to assign a unique Vehicle ID for the visit. Recognizable vehicles (for example with unique decals, customization, or other visible identifiers on the vehicle, boat, trailers, or RVs) were recorded as repeat visitors, but given a unique Vehicle ID for each distinct visit. Site visit duration calculations were limited to boat visits with both an arrival and exit photo.

For counter events that could be photo-validated, 'false' events such as BC Hydro, forestry, road maintenance and construction-related vehicles, RCMP and Conservation Officer Service vehicles, all-terrain vehicles, motorbikes, and cyclists detected by the counter were noted and excluded from the site visit data sets unless they were explicitly using the boat ramp (e.g., RCMP boats, BC Hydro boats).

Photos that did not correspond to a counter event (e.g., photos of wildlife, vegetation, or weather events) were ignored unless there was a vehicle in the photo that was not detected by the counter; in this case a record was added using the photo time stamp to fill in the date and time fields. Photo success was recorded for each counter event based on whether or not the event had a corresponding photo.

Similarly, day of the week was coded as Weekday or Weekend, including statutory holidays. For each date and site, we coded equipment operation to identify days with no equipment (e.g., during site closure periods), counter only, camera only, or both counters and cameras functioning. We also coded site data as:

- Control (0, 1, 2 corresponding to no improvement, boat ramp improved, campground improved)
- Treatment (0, 1 corresponding to pre- or post-treatment data)

Converting Raw Data to Site Use Estimates

For each monitoring day, we calculated the total number of unvalidated counter records (UVRecCount – **Maximum Estimated Visits**), the total number of photo-validated records (PVRecCount – **Index of Effort**), the total number of photo-validated Vehicle IDs (PVCarID – **Daily Total Visits**), and the total number of photo-validated boat visits (PVBoatRec – **Daily Boat Visits**). Photo-validated counter events provide a minimum estimate of the number of vehicle visits (unique vehicle IDs) and boat visits per day (PVBoatRec), i.e., calculating minimum use estimates.

We used the equipment manufacturer's specifications as a guide to identify and remove redundant (duplicate) counter events, which can occur when a vehicle travels slowly past or parks near the counter. A series of counter events within 10 seconds of each were deemed redundant to the first event of the series unless a second photo-validated event was logged during this interval. The number of redundant events in the counter data set depends largely on the placement of the counter (i.e., the location relative to the boat launch, as well as speed/movement of traffic moving along the access roads).

Counter units function at nearly 100% reliability, based on manual index counts conducted in Year 2, while photo success varied among sites and years. We used photo success as a correction factor for site visit estimates. This correction factor was used to adjust the number of unique photo-validated users to estimate annual site use at each location. This method also enables the calculation of upper and lower confidence limits around the estimate. The lower limit is photo-validated users, while the upper limit is the total counter events divided by theoretical site use patterns: dividing by 2 (arrival - exit) at Cut Thumb Bay (38 Mile), Six Mile Bay (43 Mile), Finlay Bay (76 Mile), and Dunlevy; dividing by 4 (down loaded - up empty - down empty - up loaded) at Elizabeth Creek and Alexander Mackenzie Landing.

Output Data

Primary response variables

- Total Count of Site Users (daily total of unique car IDs)
- Total Count of Site Users with Boats (daily total of unique boats)

Input data

- Site (1 – 6, corresponding to each of the 6 recreation sites)
- Monitoring Year (1- 10, corresponding to 2009 – ~~2019~~2018)
- Monitoring Day (1 – 171, corresponding to May 14 – October 31 annually)
- Month (5 – 10, corresponding to May – October)
- Control (0, 1, 2 corresponding to no improvement, boat ramp improved, campground improved)
- Treatment (0, 1 corresponding to pre- or post-treatment data)
- Total Count of Site Use Records (daily total)
- Photo Success (proportion of daily site use records that have an associated photo)
- Total Count of Repeat Users
- Reservoir Elevation (mean daily average in metres)
- Temperature (daily maximum in degrees Celsius)
- Wind (daily maximum gust wind speed)
- Total Precipitation (daily total in millimetres)
- Weekend or Statutory Holiday (0, 1)

Data Validation and Quality Assurance Protocols

Data were screened after download in the field to identify potential problems, monitor equipment battery voltage, and ensure data were transferred and secured without error. Upon return to the office each field day, data were imported to a secure project directory supported by a redundant, back up protocol.

Photo-validation was batch processed at the conclusion of each monitoring year to facilitate continuity in processing of the photos. Data entry followed a standardized procedure throughout the 10 year monitoring program, ensuring consistency in photo validation, interpretation, and formatting.

We used Visual Basic data validation routines in MS Access to automate error-checking of input data, tabulate daily counts, and format data for statistical analyses.

Data Analyses

Analytical Framework and Model Specifications

We used generalized linear mixed effects (GLMM) multiple regression models for count data to analyze whether the number and timing of boat visits changed as a result of boat ramp improvements. The design was a before-after-impact-control assessment of daily site visits, with monitoring over 171 consecutive days (May 14 – October 31) annually for 10 years (2009 – 2018). Treatments included boat ramp improvements at 2 sites, campground improvements at 2 sites, and no improvements at 2 sites designated as controls. Treatment years and boat access varied among sites; therefore, changes in site visits after treatments were analyzed independently for each site.

Outcomes variables were counts of boat visits and total recreation site visits per day, for which we considered Poisson and negative binomial data distributions to account for over-dispersion in the data (Ozmen and Famoye 2007, Zeiless 2013 – note, not cited in bibliography). The number of boat visits per day was derived from photo-validated counter data, so we tested the possibility that boat visit counts were proportional to photo success (the percent of counter events that had a corresponding photo) by including daily photo success as an index of effort (i.e., offset) in the models.

To evaluate the impact of site improvements on the number and timing of boat visits, we modeled daily boat visits as a function of a 2-way interaction (where the change in one of the main effects depends on the level of the other main effect) of *Reservoir Elevation* and *Treatment* (before and after) for the 4 sites with improvements. We expected that weather conditions and day of week would influence site use patterns and recreational boating on the reservoir so we included *Daily Maximum Temperature*, *Daily Total Precipitation*, *Maximum Daily Wind Gust* and *Weekend* to control these influences as fixed-effect variables. All continuous variables were standardized by centering on the mean. We considered monitoring years and sites as random effects with intercept (i.e., baseline levels of mean daily counts) varying among years and sites.

Model Selection & Diagnostics

The primary outputs of the analysis are quantitative parameter estimates describing how the outcome variable changes as a function of explanatory variables. This equates to a model-building approach, rather than a hypothesis-testing approach. The best model for the data was selected based on differences in Akaike's Information Criterion (AIC; Burnham and Anderson 2002 note, not cited in bibliography). When models were deemed to be equivalent (delta AIC <2), we reported results for the most parsimonious model.
We report the results of the full models with all variables of interest so that results and effect sizes can be directly compared among sites.

We assessed standard diagnostic plots of model results to evaluate whether the statistical assumptions of GLMM regression were reasonably met, including quantile-quantile plots to assess normality of residuals and leverage plots to identify potential outliers in the data. Outliers were removed from the dataset where warranted. We used likelihood ratio tests to evaluate whether negative binomial models were an improvement over standard Poisson models. The significance of categorical variables was tested using analysis of variance (ANOVA) and likelihood ratio statistics to compare models with and without the variable, allowing the dispersion parameter to be re-estimated for each model. We used Tukey's multiple post-hoc comparisons to test linear hypotheses about differences among the levels of each categorical variable. Significance of hypothesis tests were evaluated at $\alpha = 0.05$.

We produced a correlation matrix of input variables and computed generalized variance inflation factor statistics for all models to assess the potential for inflated standard error estimates due to collinearity or multicollinearity among input variables. Correlations >0.9 and VIF values >10 were considered extreme. Principal component analysis provided insight to the relationship among correlated input variables.

Interpretation of Results

Generalized linear mixed models incorporate both fixed-effects parameters and random effects in a linear predictor, via maximum likelihood. The linear predictor is related to the conditional mean of the response through the inverse link function defined in the GLM family.

In linear regression, coefficients estimate the change in the mean response per unit increase in X when all other predictors are held constant. Count data modeled as Poisson or negative binomial distributions produce estimates on the logarithmic scale, where regression coefficients are the difference between the log of expected counts (equivalent to the log of the ratio of expected counts). As such, model results (coefficients) can be interpreted as the estimated percent change (increase or decline) in counts attributed to a one unit change in each input variable when all other inputs are held constant. For example, a reservoir elevation coefficient of 0.06 tells us that for every one unit increase in reservoir elevation the log odds of visits increases by 0.06. The exponentiated coefficients, also known as

Incidence Rate Ratios (IRR), can be easier to interpret. With IRR, the expected count is multiplied by a factor of the coefficient when the independent variable increases by 1 unit. For example, with a variable like *Treatment* that has values of 0 and 1, an IRR of 0.7 means that when *Treatment* = 1 there will be 0.7 times the incident events as when *Treatment* = 0, when all other inputs are held constant.

Categorical variables were coded to compute treatment contrasts, where the number of contrasts was equal to the number of levels in the variable and the levels were ordered from lowest to highest. The coefficients for each level are therefore interpreted as the estimated differences between the average of each level and the average in the baseline level. For standardized continuous variables, the reference point for coefficient estimates is the mean of the observed values.

Graphics

To illustrate the effect of reservoir elevation and boat ramp improvements on the number and seasonal timing of daily visits, we produced plots of site visits as a quadratic function of monitoring day at varied water levels across the annual monitoring period, before and after site improvements. We defined Low, Moderate, and High water levels by binning all observed values of *Reservoir Elevation* into equal thirds. We binned *Monitoring Day* into 3 categories: Early Season (Day 0 – 50), Mid-Season (Day 51 – 100), and Late Season (Day 101 – 171).

Software

This analysis was completed using **R software** (R Development Core Team 2012) version 3.6.0 2019-04-26 with **lme4** (ver. 1.1-21) and **ggplot2** (ver. 3.2.0) packages.

RESULTS

Data Summary

Site Monitoring Data

The 10-year (2009 – 2018) monitoring program produced 156,147 traffic counter events (UVRecCount) and 339,712 photos. Data processing resulted in 101,131 photo-verified counter events (PVRecCount) and 31,701 site visits (Vehicle IDs). Complete visits with photos of both the first arrival and final exit were recorded for 20,096 visits. Traffic counters were highly reliable and operational through 90.9% of the total monitoring program; exceptions include site closures during construction and dates when the start of annual monitoring was delayed due to administrative or logistic constraints. Overall photo success for all sites and years combined was 68.6% (range 19 – 99 % among sites and years).

Reservoir Elevation Data

Reservoir elevation ranged from 656.3 masl to 672.0 masl during the 10-year monitoring program, with the lowest one third of all observed values < 667.2 masl, and the highest one third > 669.7 masl. In all years, the general pattern was for reservoir water elevation to rise rapidly from the lowest levels annually in early spring, reaching a peak in mid-summer (approx. Day 75; July 27), and then marginally declining into the fall as the reservoir draws down through normal operations (**Figure 3**). Year 2010 was an anomalous year with particularly low reservoir levels; the reservoir did not peak until fall 2010 with water elevation remaining below 665 masl until after Day 150 (October 10). Extreme fluctuations were observed, with the lowest levels of reservoir elevation recorded in May 2011 and the highest just over a year later, in July 2012. Reservoir levels reached a maximum of 671.9 masl on July 30 2012, causing the spillway at the WAC Bennett dam to be opened; this last occurred in July 2002.

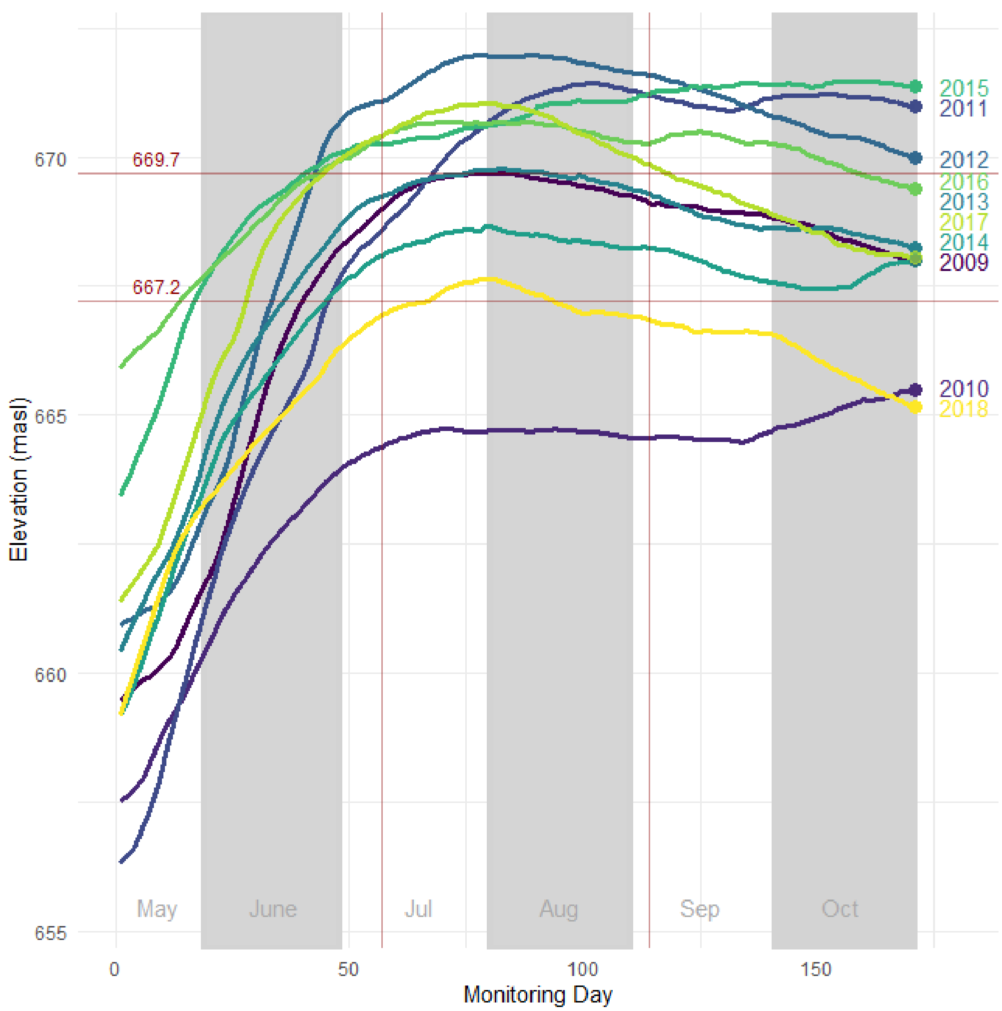


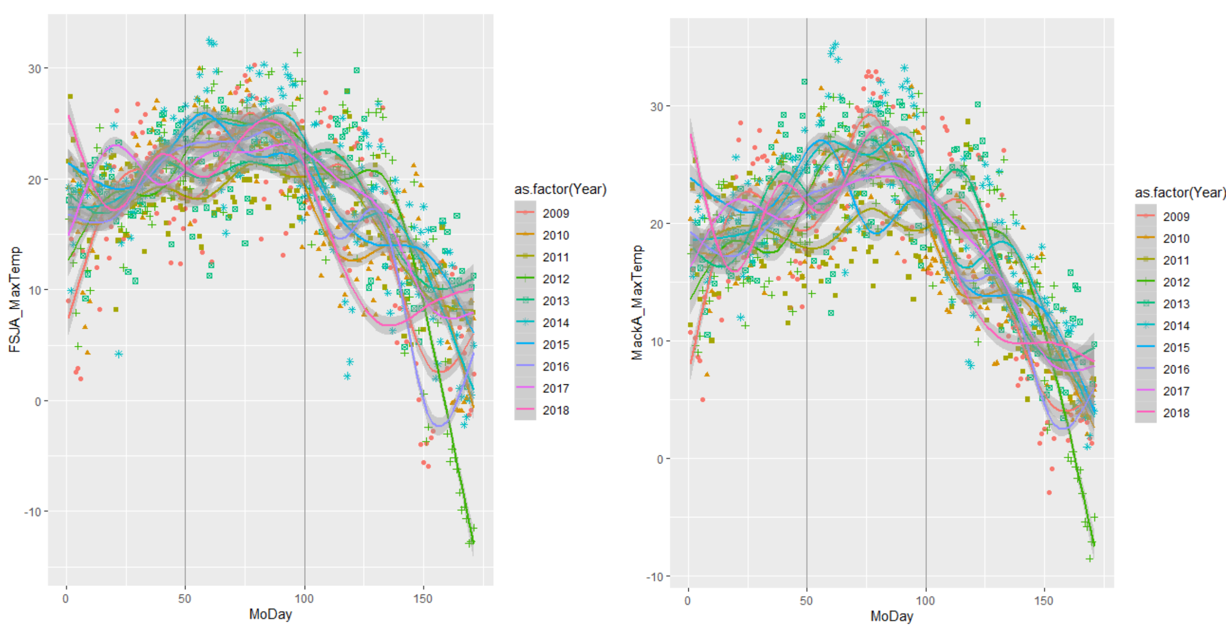
Figure 3. Williston Reservoir daily average elevation reported by BC Hydro during the 10-year (2009 – 2018) recreation site monitoring program. Monitoring day 1 corresponds to May 14 while monitoring day 171 corresponds to October 31 annually.

Weather Data

At Fort St John (Environment Canada weather station FSJA), maximum daily temperatures ranged from -12.9 to 32.5 °C during the 10-year monitoring program (**Figure 4**). The maximum daily temperature averaged over all years increased from 19.29 °C on Day 1 (May 14) to a maximum of 25.73 °C on Day 84 (August 5), and declined to a low of 1.84 °C on Day 168 [4.24 °C on Day 171 (October 31)]. At Mackenzie (MackA weather station) maximum daily temperatures ranged from 2.92 to 27.45 °C. Averaged over all years, maximum daily temperatures increased from 19.74 °C on Day 1 (May 15) to 27.45 °C on Day 89 (August 10) and declined to a low of 2.73 °C on Day 168 (October 28) [4.44 °C on Day 171].

Daily precipitation ranged from 0 to 57.0 mm (median 1.20 mm and 13.44 mm maximum, averaged over 10 years) at Fort St John, and 0 to 49.3 mm (median 0.86 mm and 9.77 mm maximum, averaged over 10 years) at Mackenzie during the monitoring program (**Figure 5**). 2011 was an anomalous year, with heavy precipitation causing localized flooding.

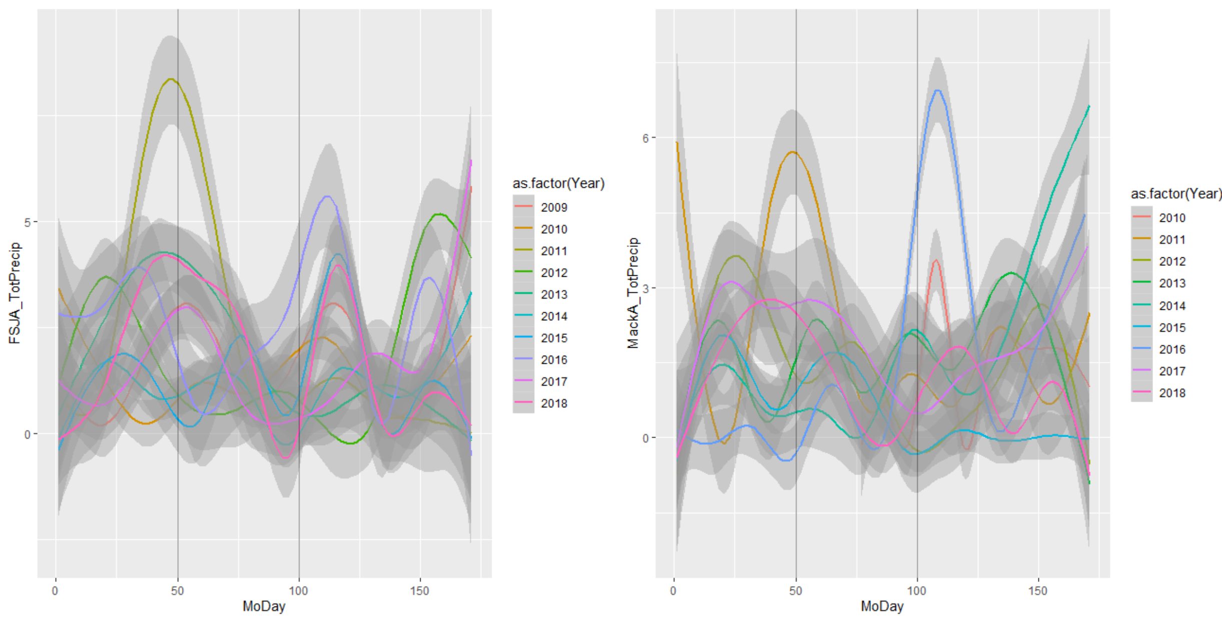
Maximum daily wind gusts recorded at the weather stations were variable at Fort St John (42.1% Low, 19.3 % Moderate, 38.6% High) and predominantly low at Mackenzie (58.9% Low, 24.9% Moderate, 16.2% High).



(a) Fort St John, BC

(b) Mackenzie, BC

Figure 4. Daily maximum temperature in degrees Celsius recorded at Environment Canada weather stations (a) FSJA in Fort St John and (b) MackA in Mackenzie during the 10-year (2009 – 2018) recreation site monitoring program. Monitoring day 1 corresponds to May 14 while monitoring day 171 corresponds to October 31 annually.



(a) Fort St John, BC (b) Mackenzie, BC

Figure 5. Daily total precipitation in mm recorded at Environment Canada weather stations (a) FSJA in Fort St John and (b) MackA in Mackenzie during the 10-year (2009 – 2018) recreation site monitoring program. Monitoring day 1 corresponds to May 14 while monitoring day 171 corresponds to October 31 annually.

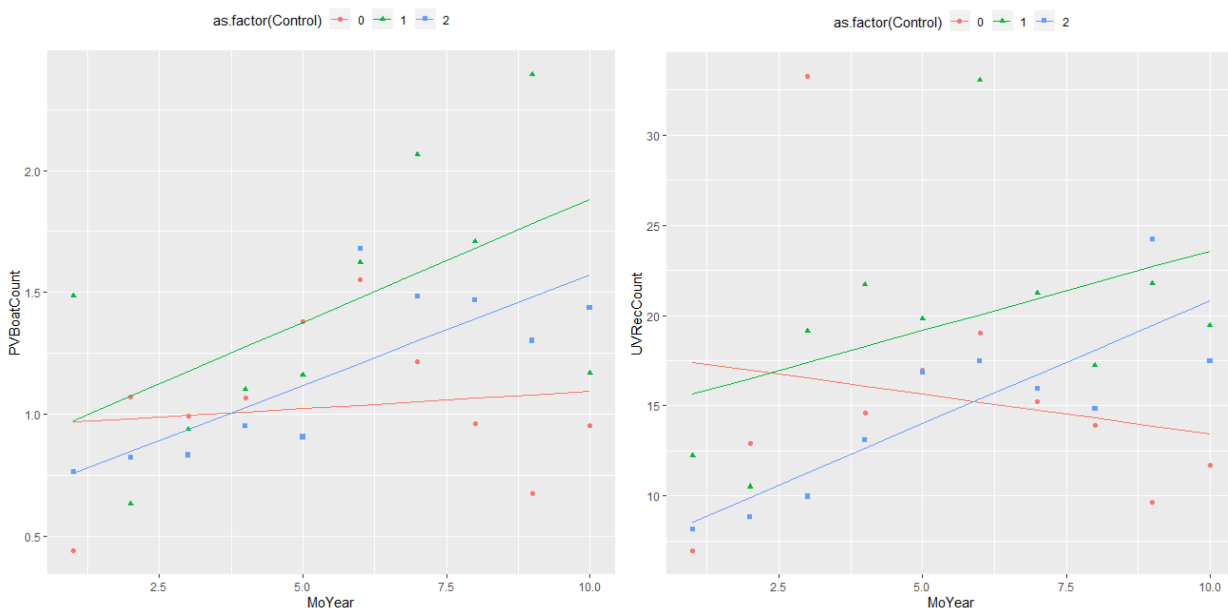
10-Year Trends in Site Visits

Comparison of Treatment and Control Sites

The 10-year trend in mean daily boat count (boat visits?) indicated no increase at control sites (Elizabeth Creek and Finlay Bay) where no improvements were made, and an increasing trend at sites where boat ramps were improved (Dunlevy and Mackenzie Landing). A similar increasing trend was observed at sites where campgrounds were improved (Cut Thumb and Six Mile), although mean daily boat counts were lower overall at these sites (**Figure 6a**).

The trends in mean daily boat count were estimated as an average 4% decline annually for control sites (Elizabeth Creek and Finlay Bay) and approximately 9% average increase at sites with improved boat ramps, once influential variables were accounted for in multiple regression analyses (**Table 4**).

Total site visits declined by 6% on average at control sites but increased at improved sites, with the greatest increase at sites with campground improvements (**Figure 6b, Table 4**).



(a) Mean Daily Boat Visits (b) Mean Daily Total Visits

Figure 6. Linear 10-year trends in (a) mean daily boat visits and (b) mean daily total visits at 2 sites with no improvements (treatment = 0), 2 sites with improved boat ramps (treatment = 1), and 2 sites with improved campgrounds (treatment = 2).

Table 4. Generalized linear mixed effect models of the 10-year trend in (a) mean daily boat visits and (b) mean daily total visits at 2 sites with no improvements (treatment = 0), 2 sites with improved boat ramps (treatment = 1), and 2 sites with improved campgrounds (treatment = 2). Reservoir water level, weather, and day of the week were controlled as influences on mean daily boat visits and total site visits.

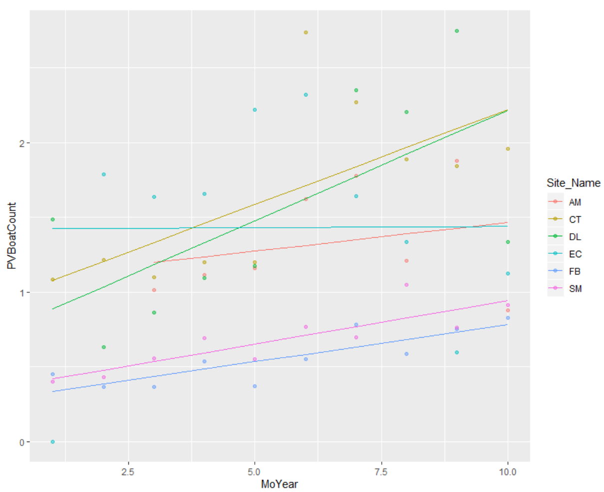
	Boat Counts		Site Use Counts	
Predictors	Estimate (IRR)	p	Estimate (IRR)	p
(Intercept)	-0.57 (0.57)	0.065	2.2 (9.08)	**<0.001**
Monitoring Year	-0.04 (0.96)	**<0.001**	-0.06 (0.94)	**<0.001**
Control 1 – Ramp Improvements	-0.44 (0.64)	0.312	-0.03 (0.97)	0.947
Control 2 – Campground Improvements	-0.62 (0.54)	0.151	-0.84 (0.43)	0.093
Reservoir Elevation	0.02 (1.02)	**0.010**	0.02 (1.02)	**<0.001**
Reservoir Elevation (Squared)	0.00 (1.00)	0.514	0.01 (1.01)	**<0.001**
Air Temperature	0.08 (1.08)	**<0.001**	0.03 (1.03)	**<0.001**
Precipitation	0.003 (1.00)	0.383	0.02 (1.00)	0.221
Wind Gust Moderate	-0.05 (0.95)	0.242	-0.03 (0.97)	0.288
Wind Gust High	-0.16 (0.85)	**<0.001**	-0.05 (0.95)	0.061
Year and Control Group 1 (Interaction)	0.13 (1.13)	**<0.001**	0.07 (1.07)	**<0.001**
Year and Control Group 2 (Interaction)	0.10 (1.11)	**<0.001**	0.13 (1.14)	**<0.001**
Random Effects				
σ^2	1.08		0.69	
τ_{00}	0.18 $_{Site}$		0.25 $_{Site}$	
ICC	0.14		0.27	
N	6 $_{Site}$		6 $_{Site}$	
Observations	8354		8318	

Marginal R^2 / Conditional R^2	0.234 / 0.342	0.128 / 0.359

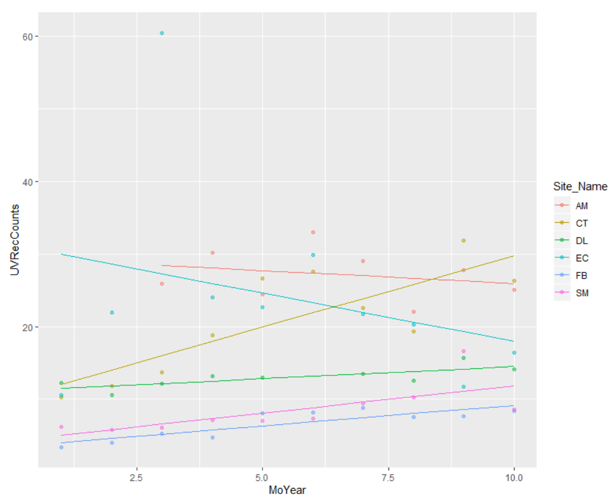
Comparison Among Sites

The 10-year trend in mean daily boat count indicated at all sites except Elizabeth Creek (**Figure 7a**). The largest rate of increase in mean daily boat count was estimated as 25% at Dunlevy, once influential variables were accounted for in multiple regression analyses (**Table 5**).

Total site visits increased the most (IRR = 1.26) at sites with campground improvements (Cut Thumb and Six Mile), and declined at Elizabeth Creek (**Figure 7b, Table 5**).



(a) Mean Daily Boat Visits



(b) Mean Daily Total Visits

Figure 7. The 10-year trend in (a) mean daily boat visits and (b) mean daily total visits at each of the 6 recreation monitoring sites: 2 with no improvements (EC and FB), 2 with improved boat ramps (DL and AM), and 2 sites with improved campgrounds (CT and 6M).

Table 5. Generalized linear mixed effect models of the 10-year trend in (a) mean daily boat visits and (b) mean daily total visits at each of the 6 recreation monitoring sites: 2 with no improvements (EC and FB), 2 with improved boat ramps (DL and AM), and 2 sites with improved campgrounds (CT and 6M). Reservoir water level, weather, and day of the week were controlled as influences on mean daily boat visits and total site visits.

	PVBoatCount		UVRecCount	
Explanatory Variables	Estimate (IRR)	p	Estimate (IRR)	p
(Intercept)	0.42 (1.53)	**<0.001**	3.58 (35.87)	**<0.001**
Monitoring Year	-0.12 (0.89)	**<0.001**	-0.17 (0.84)	**<0.001**
Mackenzie Landing	-0.95 (0.39)	**<0.001**	-0.86 (0.42)	**<0.001**
Cut Thumb Bay	-1.16 (0.31)	**<0.001**	-1.68 (0.19)	**<0.001**
Dunlevy	-1.56 (0.21)	**<0.001**	-1.64 (0.19)	**<0.001**
Finlay Bay	-2.10 (0.12)	**<0.001**	-2.52 (0.08)	**<0.001**
Six Mile Bay	-2.06 (0.13)	**<0.001**	-2.55 (0.08)	**<0.001**
Reservoir Elevation	0.02 (1.02)	**0.003**	-0.01 (0.99)	0.072
Air Temperature	0.08 (1.08)	**<0.001**	0.03 (1.04)	**<0.001**
Precipitation	<0.01 (1.00)	0.432	<0.01 (1.00)	0.618
Wind Gust Moderate	-0.05 (0.95)	0.261	-0.04 (0.96)	0.161
Wind Gust High	-0.16 (0.85)	**<0.001**	-0.06 (0.94)	**0.028**
Year and Site Interaction (Mackenzie Landing)	0.10 (1.10)	**<0.001**	0.15 (1.17)	**<0.001**
Year and Site Interaction (Cut Thumb Bay)	0.18 (1.20)	**<0.001**	0.24 (1.27)	**<0.001**
Year and Site Interaction (Dunlevy)	0.25 (1.28)	**<0.001**	0.18 (1.20)	**<0.001**
Year and Site Interaction (Finlay Bay)	0.16 (1.18)	**<0.001**	0.20 (1.22)	**<0.001**

Year and Site Interaction (Six Mile Bay)	0.18 (1.20)	**<0.001**	0.24 (1.27)	**<0.001**
Observations	8354		8318	
Nagelkerke's R^2	0.308		0.420	

Response to Boat Ramp Improvements

Dunlevy

Reservoir water levels had a significant influence on boat visits at Dunlevy, with an average 14% increase in boat visits per 1 m increase in reservoir elevation (conditional on all other input variables remaining constant), prior to boat ramp improvements (**Figure 8a, Table 6**). On average, the number of boat visits increased twofold after boat ramp improvements (Treatment IRR = 2.11), but the effect was moderated by a significant interaction of Elevation and Treatment (**Table 6**). The interaction of Elevation and Treatment reflects a larger increase in mean daily boat visits early in the season (at lower elevations) compared to later in the season (at higher elevations). The effect of reservoir elevation declined after ramp improvements. This interpretation is supported by the plot of boat visits as a quadratic function of monitoring day, which showed a shift in peak use from mid-season (Day 80; August 1st) before ramp improvements to early season (<Day 50; May 14 – July 1) after improvements (**Figure 9**). Total visits also shifted to peak about 30 days earlier post-improvement (**Figure 9**).

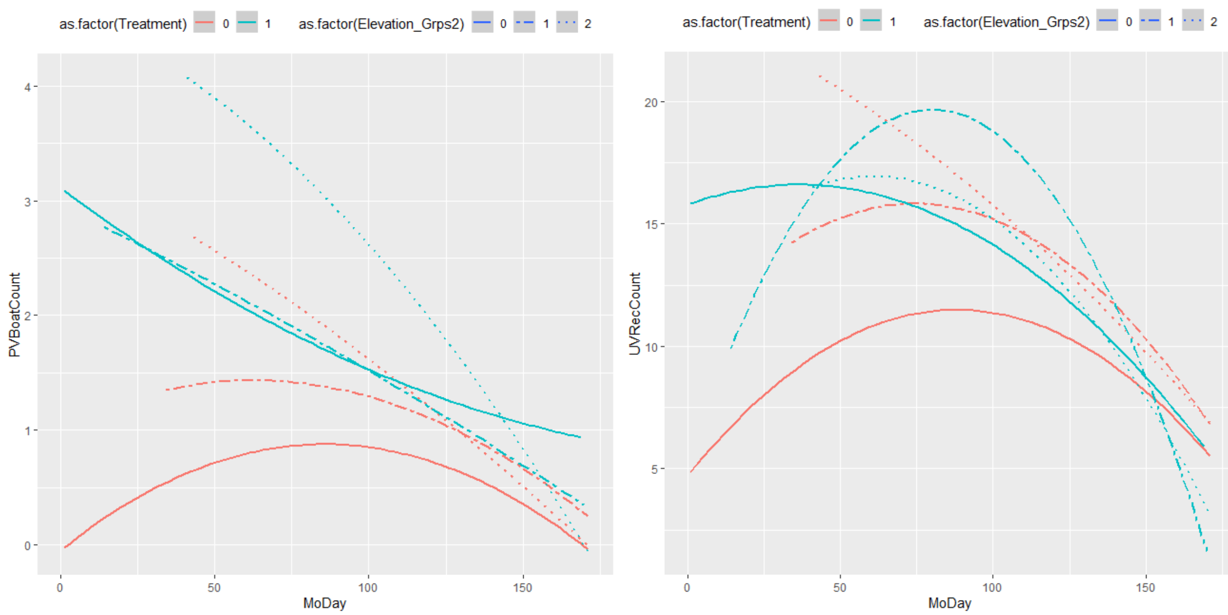
Daily maximum temperature was a significant influence on boat visits and total visits, but daily precipitation and wind gust were not important predictors of site use at Dunlevy (**Table 6**). Boat visits were 2.3 times more likely on weekends (**Table 6**).

Q1. Did recreational use of the boat ramp increase after boat access was improved?

Yes. On average, the number of boat visits increased two-fold after boat ramp improvements (Treatment IRR = 2.11), but the overall effect was moderated by a significant negative interaction of Elevation and Treatment. The interaction indicated that the effect of reservoir elevation declined after ramp improvements, with the greatest increase in boat visits occurring at lower elevations (i.e., earlier in the season; **Figure 8a, Table 6**).

Q2. Did seasonal use change with improved boat access during low reservoir levels?

Yes. Peak boat visits shifted from mid-season (Day 80; August 1st) before ramp improvements to early season (<Day 50; May 14 – July 1) after improvements (**Figure 9**).



(a) Mean Daily Boat Visits (b) Mean Daily Total Visits

Figure 8. Seasonal trend in (a) mean daily boat visits and (b) mean daily total visits at **Dunlevy** recreation site during low, moderate, and high reservoir water levels, before and after boat ramp improvements. Daily boater use count (points) as a function of monitoring day and reservoir elevation (line). Monitoring day 1 corresponds to May 14 while monitoring day 171 corresponds to October 31.

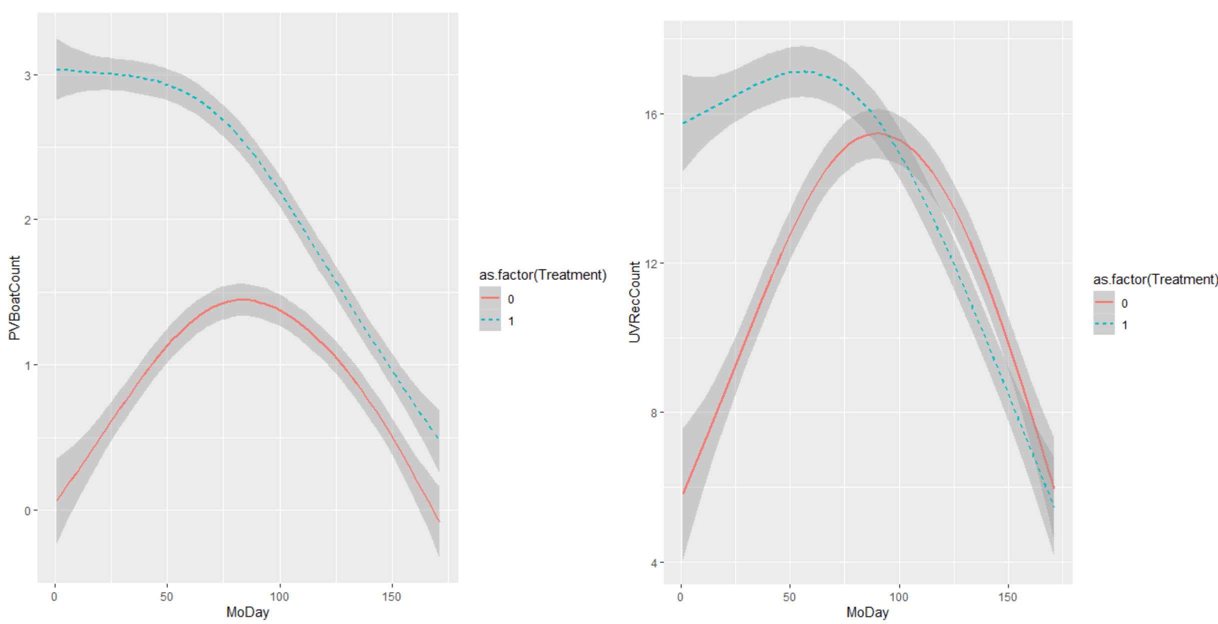


Figure 9. Seasonal trend in (a) mean daily boat visits and (b) mean daily total visits at **Dunlevy** recreation site, before and after boat ramp improvements. Reservoir water level, weather, and day of the week were controlled as influences on mean daily boat visits and total site visits.

Table 6. Generalized linear mixed effect models of reservoir water level, weather influences, and day of the week on mean daily boat visits and total site visits at **Dunlevy** recreation site, before and after boat ramp improvements (treatment).

Dunlevy	Boat Count (Photo Validated)		Site Use (Counter Events)	
Predictors	Estimate (IRR)	p	Estimate (IRR)	p
Intercept	-1.12 (0.33)	**<0.001**	1.69 (5.44)	**<0.001**
Treatment	0.75 (2.11)	**<0.001**	-0.12 (0.89)	0.321
Elevation	0.14 (1.16)	**<0.001**	0.06 (1.06)	**<0.001**
Temperature	0.06 (1.06)	**<0.001**	0.03 (1.03)	**<0.001**
Precipitation	-0.002 (1.00)	0.829	0.006 (1.01)	0.114
Wind Gust (Moderate)	-0.04 (0.96)	0.638	-0.04 (0.96)	0.527
Wind Gust (High)	-0.04 (0.96)	0.618	-0.01 (0.99)	0.789
Weekend	0.84 (2.30)	**<0.001**	0.74 (2.09)	**<0.001**
Treatment x Elevation	-0.18 (0.83)	**<0.001**	-0.06 (0.94)	**0.001**
Random Effects				
σ^2	0.81		0.41	
τ_{00}	0.01 $_{\text{MoYear}}$		0.02 $_{\text{MoYear}}$	
ICC	0.02		0.06	
N	9 $_{\text{MoYear}}$		9 $_{\text{MoYear}}$	
Observations	1309		1310	
Marginal R^2 / Conditional R^2	0.411 / 0.421		0.295 / 0.336	

Mackenzie Landing

Reservoir water levels were found to have a significant influence on boat visits at Mackenzie Landing, with an average 6% increase in boat visits per 1 m increase in reservoir elevation (conditional on all other input variables remaining constant) , prior to boat ramp improvements (**Figure 10a, Table 7**). There was no evidence of an increase in boat visits following boat ramp improvements (**Table 7**), nor was there any evidence that the effect of reservoir elevation changed post-improvement (i.e., no significant interaction of Treatment and Elevation). Boat visits at this site peaked in mid-season; there was no difference in the seasonal timing of either total visits or boat visits pre-and post- boat ramp improvements (**Figure 11**).

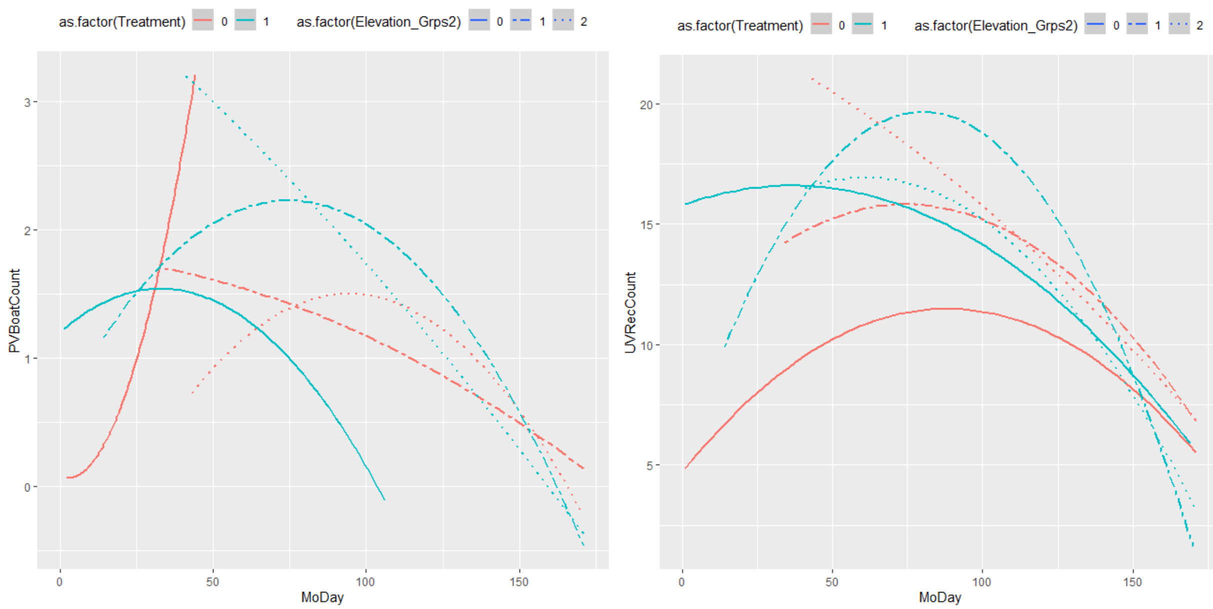
Daily maximum temperatures and daily maximum wind gust were significant influences on boat visits and total visits, but daily precipitation was not an important predictor of site use at Mackenzie Landing (**Table 7**). Wind had a greater effect on boat visits than total visits, but both were reduced as wind gusts increased from low to moderate and high categories. Boat visits were 2.7 times more likely on weekends (**Table 7**).

Q1. Did recreational use of the boat ramp increase after boat access was improved?

No. There was no evidence that the number of boat visits increased after boat ramp improvements at Mackenzie Landing (**Figure 10a, Table 7**).

Q2. Did seasonal use change with improved boat access during low reservoir levels?

No. There was no significant difference in the timing of peak boat visits before and after ramp improvements (**Figure 11**).



(a) Mean Daily Boat Visits (b) Mean Daily Total Visits

Figure 10. Seasonal trend in (a) mean daily boat visits and (b) mean daily total visits at **Mackenzie** recreation site during low, moderate, and high reservoir water levels, before and after boat ramp improvements.

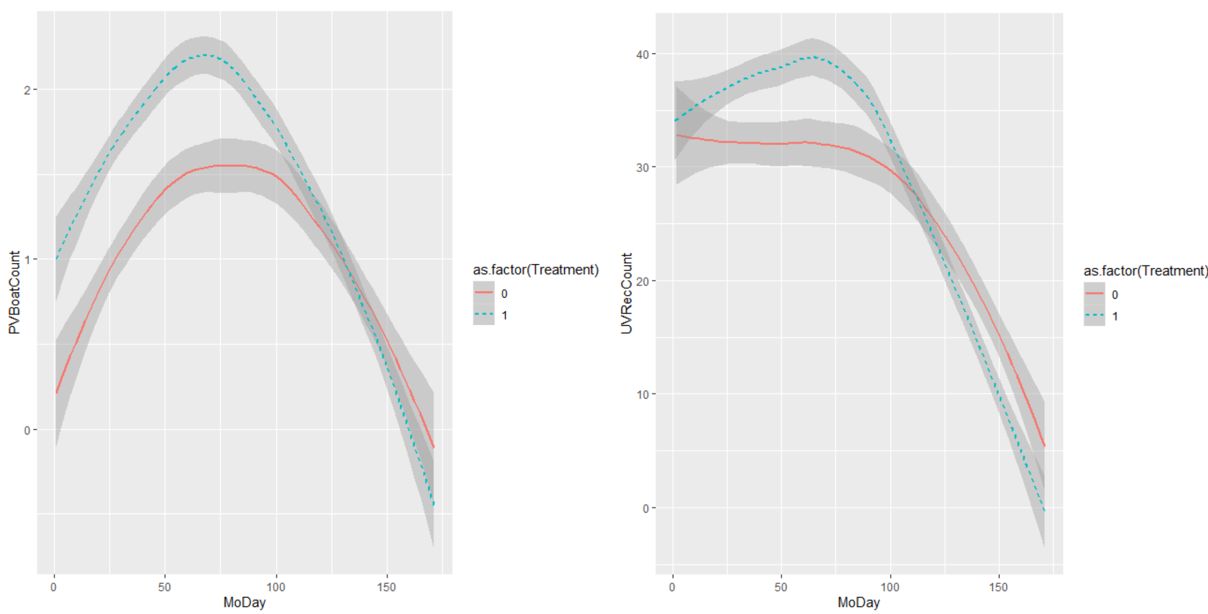


Figure 11. Seasonal trend in (a) mean daily boat visits and (b) mean daily total visits at **Mackenzie Landing** recreation site, before and after boat ramp improvements. Reservoir water level, weather, and day of the week were controlled as influences on mean daily boat visits and total site visits.

Table 7. Generalized linear mixed effect models of reservoir water level, weather influences, and day of the week on mean daily boat visits and total site visits at **Mackenzie Landing** recreation site, before and after boat ramp improvements.

	Boat Counts (Photo Validated)		Site Use (Counter Events)	
Predictors	Estimate (IRR)	p	Estimate (IRR)	p
Intercept	-1.13 (0.32)	**<0.001**	3.00 (20.12)	**<0.001**
Treatment	0.07 (1.07)	0.658	-0.02 (0.98)	0.801
Elevation	0.07 (1.07)	**<0.001**	-0.03 (0.97)	**<0.001**
Temperature	0.09 (1.10)	**<0.001**	0.07 (1.07)	**<0.001**
Precipitation	-0.01 (0.99)	0.249	-0.002 (1.00)	0.669
Wind Gust (Moderate)	-0.33 (0.72)	**<0.001**	-0.14 (0.87)	**0.018**
Wind Gust (High)	-0.41 (0.66)	**<0.001**	-0.23 (0.79)	**0.001**
Weekend	0.99 (2.70)	**<0.001**	0.68 (1.98)	**<0.001**
Treatment x Elevation	-0.03 (0.97)	0.354	-0.03 (0.97)	0.102
Random Effects				
σ^2	0.77		0.51	
τ_{00}	0.03 $_{\text{MoYear}}$		0.00 $_{\text{MoYear}}$	
ICC	0.04		0.01	
N	8 $_{\text{MoYear}}$		8 $_{\text{MoYear}}$	
Observations	1076		1269	
Marginal R^2 / Conditional R^2	0.442 / 0.462		0.406 / 0.411	

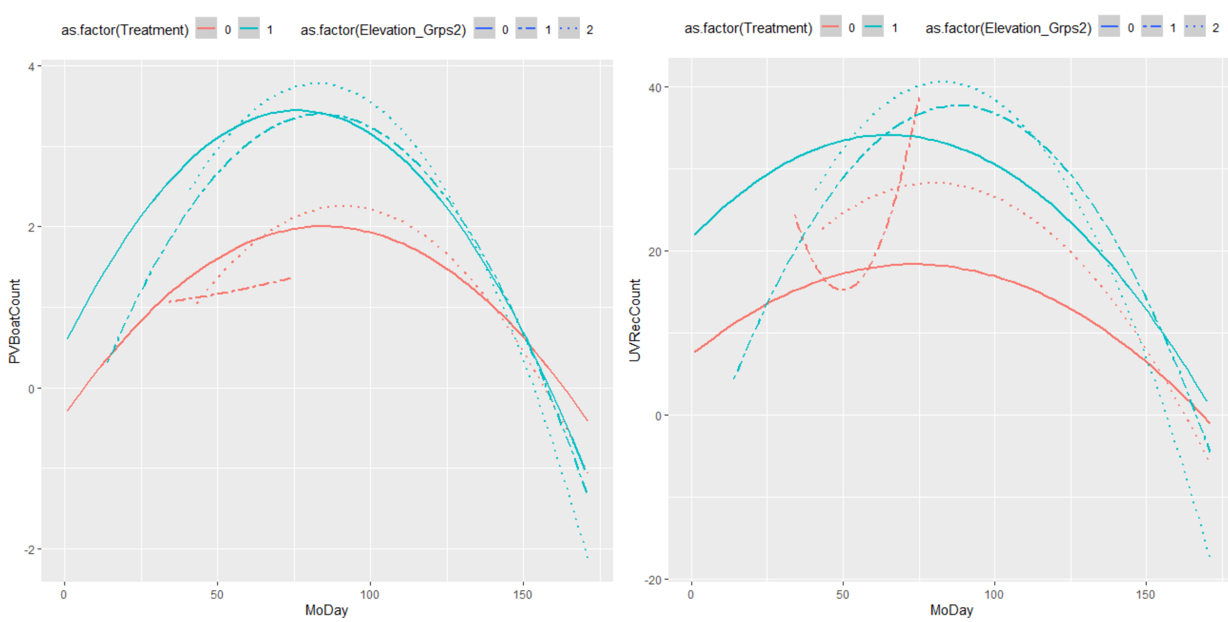
Response to Campground Improvements

Cut Thumb

Reservoir water levels were found to have a significant influence on boat visits at Cut Thumb, with an average 10% increase in boat visits per 1 m increase in reservoir elevation (conditional on all other input variables remaining constant) (**Figure 12a, Table 8**). On average, the number of daily boat visits was 1.4 times higher after campground improvements (Treatment IRR = 1.36; **Table 6**). For total visits, the positive effect of increasing reservoir elevation declined after campground improvements (i.e., there was a significant Treatment x Elevation interaction; **Table 8**).

Boat visits and total visits at this site peaked in mid-season throughout the monitoring program. There was a marginal shift in the timing of boat visits (approx. 5 days earlier) but no difference in the seasonal timing of total visits before and after campground improvements (**Figure 13**).

Daily maximum temperatures and daily maximum wind gust were significant influences on boat visits and total visits, but daily precipitation was not an important predictor of site use at Cut Thumb (**Table 8**). Wind had a greater effect on boat visits than total visits, but both were reduced as wind gusts increased from low to moderate categories. Boat visits were 1.9 times more likely on weekends (**Table 8**).



(a) Mean Daily Boat Visits (b) Mean Daily Total Visits

Figure 12. Seasonal trend in (a) mean daily boat visits and (b) mean daily total visits at **Cut Thumb** recreation site during low, moderate, and high reservoir water levels, before and after boat campground improvements.

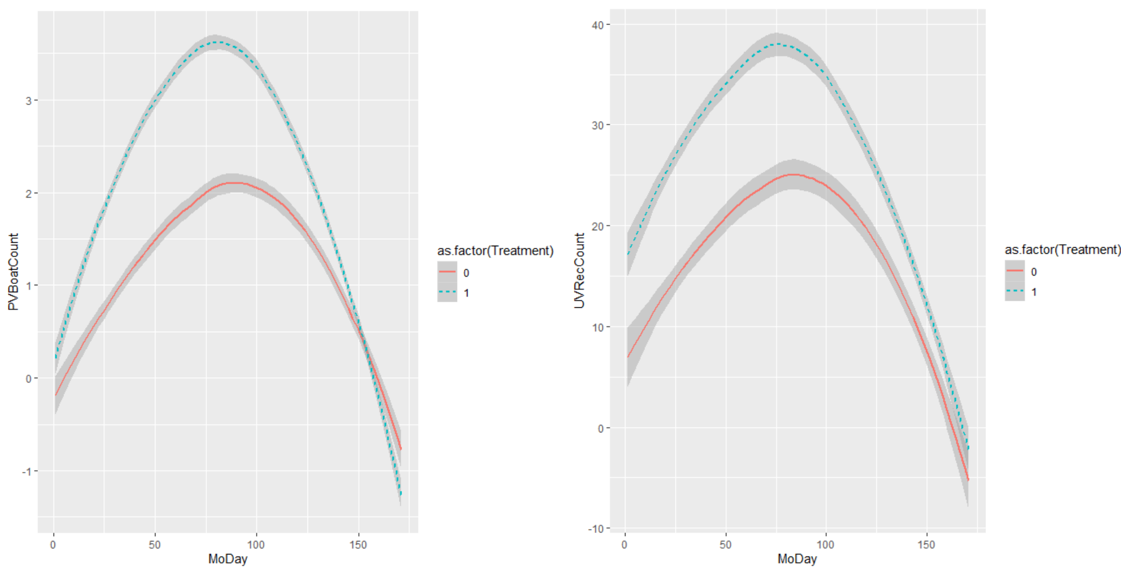


Figure 13. Seasonal trend in (a) mean daily boat visits and (b) mean daily total visits at **Cut Thumb** recreation site, before and after boat campground improvements. Reservoir water level, weather, and day of the week were controlled as influences on mean daily boat visits and total site visits.

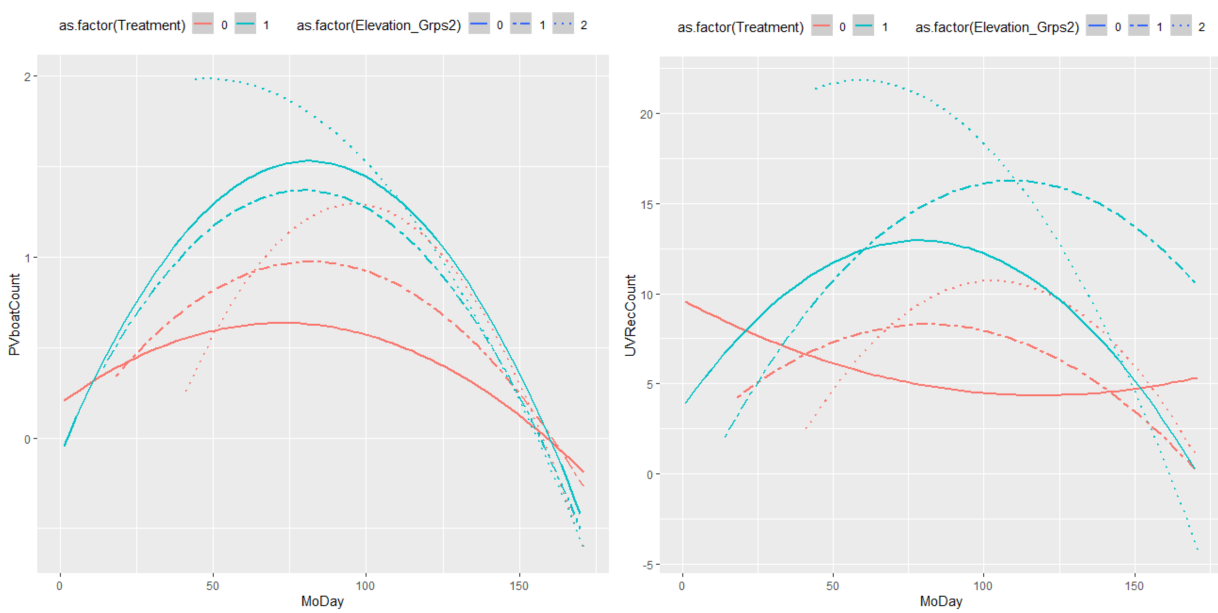
Table 8. Generalized linear mixed effect models of season, reservoir water level, and weather influences on mean daily boat visits and total site visits at **Cut Thumb** recreation site, before and after boat ramp improvements.

	Boat Count (Photo Validated)		Site Use (Counter Events)	
Predictors	Estimate (IRR)	p	Estimate (IRR)	p
Intercept	-0.86 (0.42)	**<0.001**	2.41 (11.08)	**<0.001**
Treatment	0.31 (1.36)	0.057	0.41 (1.51)	**<0.001**
Elevation	0.10 (1.10)	**<0.001**	0.05 (1.05)	**<0.001**
Temperature	0.09 (1.09)	**<0.001**	0.06 (1.06)	**<0.001**
Precipitation	0.01 (1.01)	0.215	0.002 (1.00)	0.605
Wind Gust (Moderate)	-0.28 (0.75)	**0.001**	-0.11 (0.90)	**0.038**
Wind Gust (High)	-0.18 (0.83)	0.089	-0.06 (0.94)	0.308
Weekend	0.66 (1.94)	**<0.001**	0.75 (2.11)	**<0.001**
Treatment x Elevation	-0.005 (1.00)	0.878	-0.06 (0.94)	**0.001**
Random Effects				
σ^2	0.97		0.50	
τ_{00}	0.08 $_{\text{MoYear}}$		0.05 $_{\text{MoYear}}$	
ICC	0.08		0.09	
N	10 $_{\text{MoYear}}$		10 $_{\text{MoYear}}$	
Observations	1537		1579	
Marginal R^2 / Conditional R^2	0.379 / 0.428		0.409 / 0.460	

Six Mile

Reservoir water levels were found to have a significant influence on boat visits at Six Mile, with an average 11% increase in boat visits per 1 m increase in reservoir elevation (conditional on all other input variables remaining constant) prior to campground improvements, and 15% increase with elevation after improvements (**Figure 14a, Table 9**). Total daily visits were not influenced by reservoir elevation prior to campground improvements, but increased with reservoir elevation after improvements (**Table 9**). There was a strong positive effect of increasing elevation on daily boat visits and daily total visits after campground improvements (**Table 9**). Boat visits and total visits both peaked mid-season at this site, with no significant shift in timing of site use post-improvement (**Figure 15**).

Daily maximum temperatures were a significant influence on boat visits and total visits, but daily precipitation and wind gust were not important predictors of site use at Six Mile (**Table 9**). Boat visits were 1.8 times more likely on weekends (**Table 9**).



(a) Mean Daily Boat Visits (b) Mean Daily Total Visits

Figure 14. Seasonal trend in (a) mean daily boat visits and (b) mean daily total visits at **Six Mile** recreation site during low, moderate, and high reservoir water levels, before and after boat campground improvements.

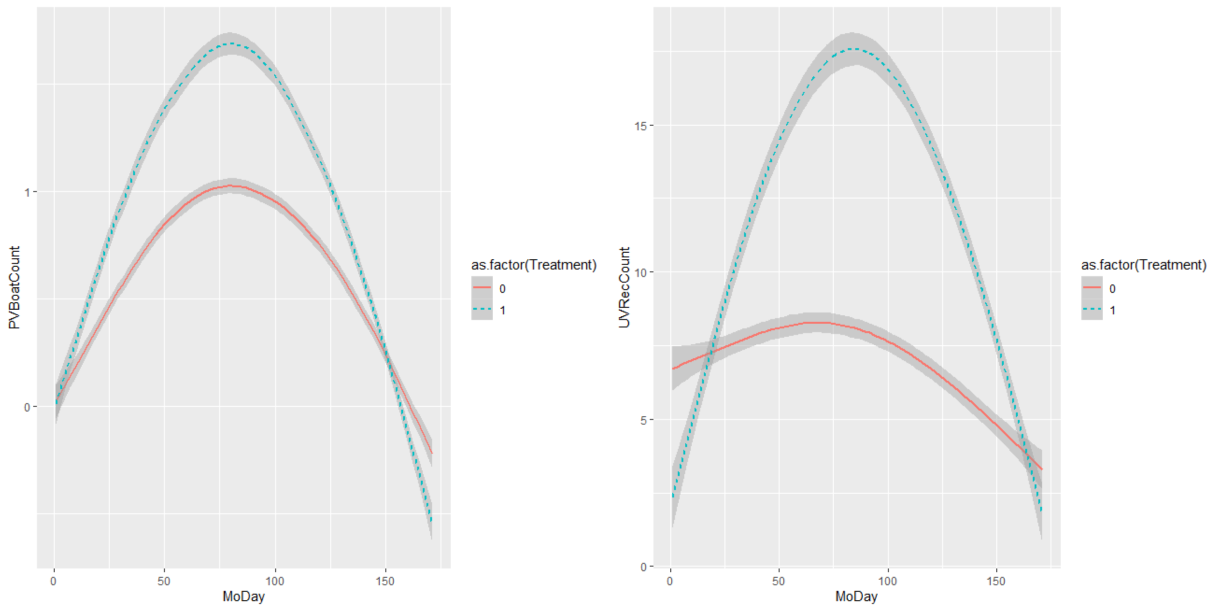


Figure 15. Seasonal trend in (a) mean daily boat visits and (b) mean daily total visits at **Six Mile** recreation site, before and after boat campground improvements. Reservoir water level, weather, and day of the week were controlled as influences on mean daily boat visits and total site visits.

Table 9. Generalized linear mixed effect models of season, reservoir water level, and weather influences on mean daily boat visits and total site visits at **Six Mile** recreation site, before and after boat ramp improvements.

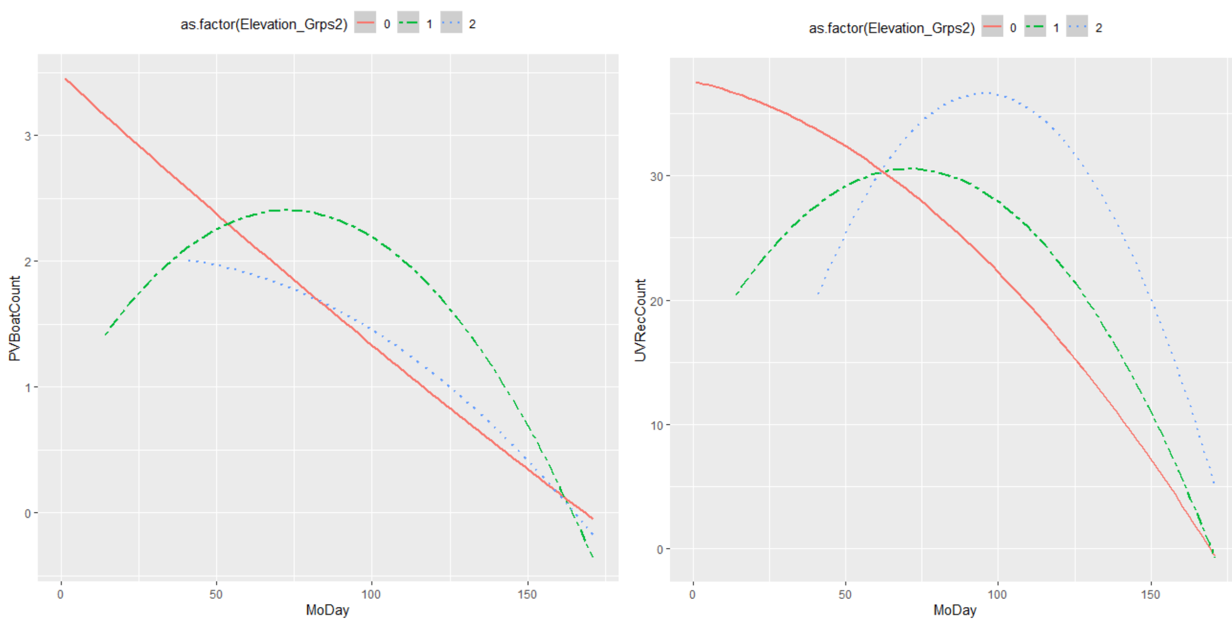
	Boat Count (Photo Validated)		Site Use (Counter Events)	
Predictors	Estimate (IRR)	p	Estimate (IRR)	p
Intercept	-1.58 (0.21)	**<0.001**	1.74 (5.70)	**<0.001**
Treatment	-0.16 (0.86)	0.535	0.13 (1.13)	0.489
Elevation	0.11 (1.12)	**<0.001**	-0.003 (1.00)	0.750
Temperature	0.07 (1.08)	**<0.001**	0.03 (1.03)	**<0.001**
Precipitation	0.009 (1.01)	0.337	0.002 (1.00)	0.760
Wind Gust (Moderate)	-0.12 (0.89)	0.235	-0.02 (0.98)	0.685
Wind Gust (High)	-0.12 (0.89)	0.343	-0.05 (0.95)	0.521
Weekend	0.59 (1.81)	**<0.001**	0.67 (1.96)	**<0.001**
Treatment x Elevation	0.15 (1.16)	**0.004**	0.11 (1.12)	**<0.001**
Random Effects				
σ^2	1.18		0.63	
τ_{00}	0.14 $_{\text{MoYear}}$		0.05 $_{\text{MoYear}}$	
ICC	0.10		0.07	
N	10 $_{\text{MoYear}}$		10 $_{\text{MoYear}}$	
Observations	1507		1579	
Marginal R^2 / Conditional R^2	0.327 / 0.397		0.202 / 0.258	

Trend Analysis at Control Sites

Elizabeth Creek

Daily boat visits and daily total visits at Elizabeth Creek were negatively correlated with reservoir elevation, with an average 11% decline in boat visits per 1 m increase in reservoir elevation (conditional on all other input variables remaining constant; **Figure 16a, Table 10**). Boat visits and total visits are highest in early season at this site (**Figure 17**).

Daily maximum temperatures and daily maximum wind gusts were significant influence on boat visits and total visits, but daily precipitation was not an important predictor of site use at Elizabeth Creek (**Table 10**). Boat visits were 2.5 times more likely on *Weekends* (**Table 10**).



(a) Mean Daily Boat Visits (b) Mean Daily Total Visits

Figure 16. Seasonal trend in (a) mean daily boat visits and (b) mean total visits at **Elizabeth Creek** recreation site during low, moderate, and high reservoir water levels. This is a control site with no improvements during the 10 year (2009 – 2018) monitoring period.

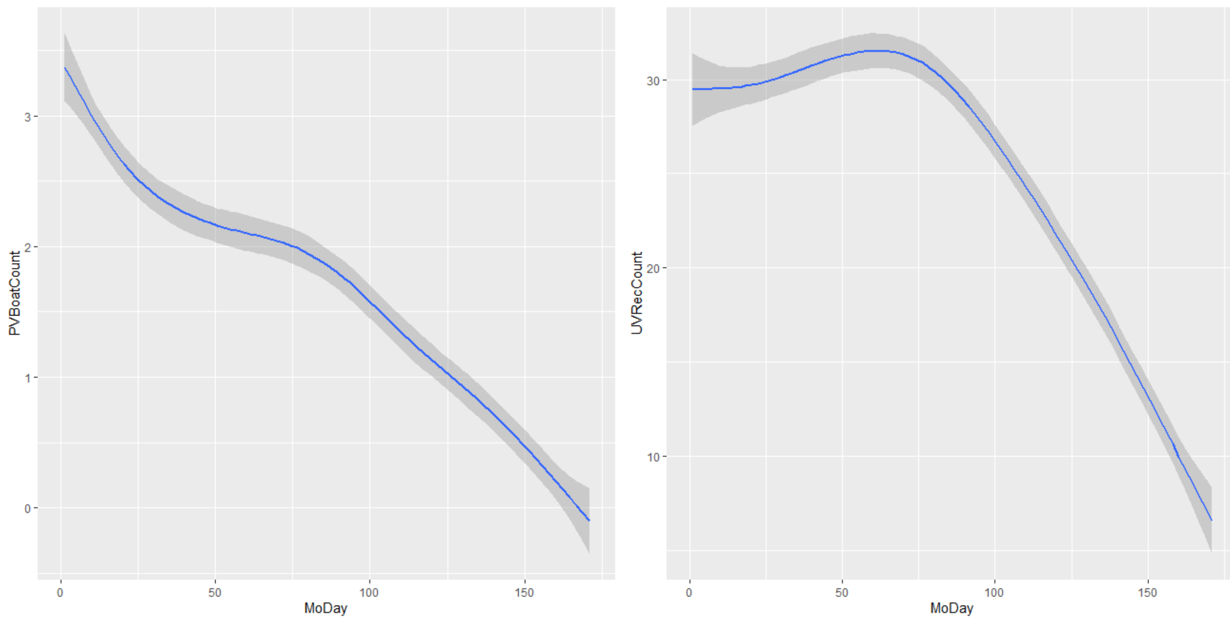


Figure 17. Seasonal trend in (a) mean daily boat visits and (b) mean daily total visits at **Elizabeth Creek** recreation site. Reservoir water level, weather, and day of the week were controlled as influences on mean daily boat visits and total site visits. This is a control site with no improvements during the 10 year (2009 – 2018) monitoring period.

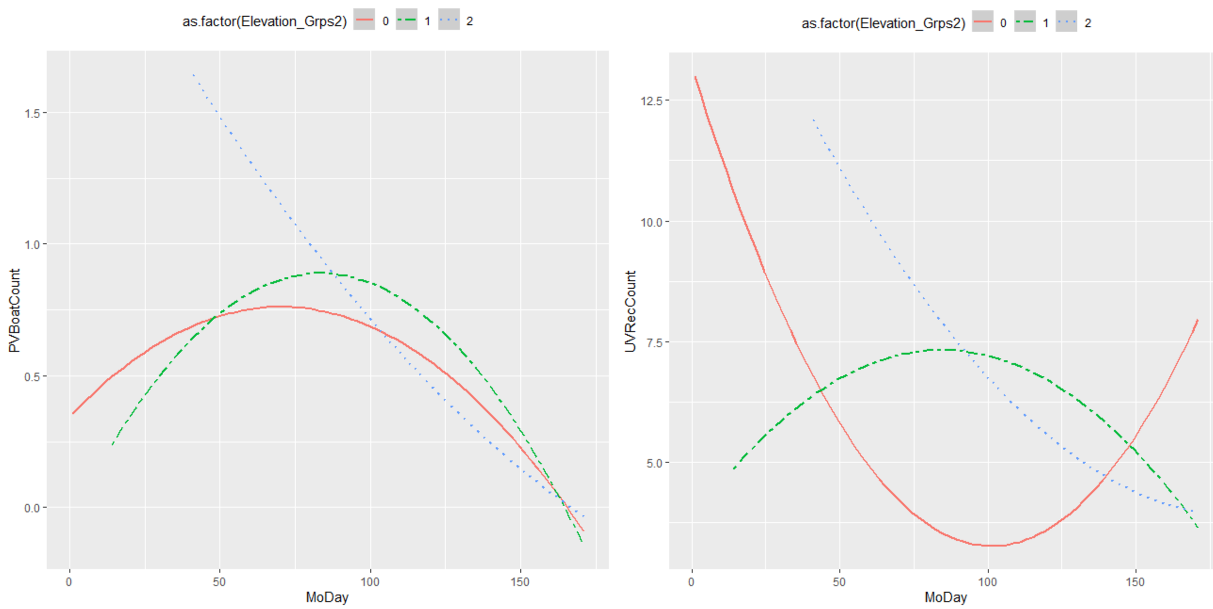
Table 10. Generalized linear mixed effect models of season, reservoir water level, and weather influences on mean daily boat visits and total site visits at **Elizabeth** Creek recreation site (control site with no improvements).

	Boat Count (Photo Validated)		Site Use (Counter Events)	
Predictors	Estimate (IRR)	p	Estimate (IRR)	p
Intercept	-0.71 (0.49)	**<0.001**	2.79 (16.20)	**<0.001**
Elevation	-0.11 (0.90)	**<0.001**	-0.03 (0.97)	**0.001**
Temperature	0.08 (1.08)	**<0.001**	0.06 (1.06)	**<0.001**
Precipitation	-0.01 (0.99)	0.384	-0.003 (1.00)	0.608
Wind Gust (Moderate)	-0.10 (0.91)	0.309	-0.08 (0.92)	0.228
Wind Gust (High)	-0.28 (0.75)	**0.001**	-0.11 (0.89)	**0.044**
Weekend	0.91 (2.49)	**<0.001**	0.65 (1.91)	**<0.001**
Random Effects				
σ^2	0.83		0.59	
τ_{00}	0.16 $_{MoYear}$		0.26 $_{MoYear}$	
ICC	0.16		0.31	
N	10 $_{MoYear}$		10 $_{MoYear}$	
Observations	1366		1573	
Marginal R^2 / Conditional R^2	0.395 / 0.491		0.241 / 0.476	

Finlay Bay

Daily boat visits at Finlay Bay were not influenced by reservoir elevation (**Figure 18a, Table 11**). Daily total visits were negatively correlated with reservoir elevation, with an average 5% decline in total visits per 1 m increase in reservoir elevation (conditional on all other input variables remaining constant; **Figure 18a, Table 11**). Boat visits peak mid-season, while total visits are highest in early season at this site (**Figure 19**).

Daily maximum temperatures were a significant influence on boat visits and total visits; precipitation was an important predictor of total visits (**Table 11**). Total visits were 1.7 times more likely on *Weekends*, but day of week had no influence on boat visits (**Table 11**).



(a) Mean Daily Boat Visits (b) Mean Daily Total Visits

Figure 18. Seasonal trend in (a) mean daily boat visits and (b) mean total visits at **Finlay Bay** Creek recreation site during low, moderate, and high reservoir water levels. This is a control site with no improvements during the 10 year (2009 – 2018) monitoring period.

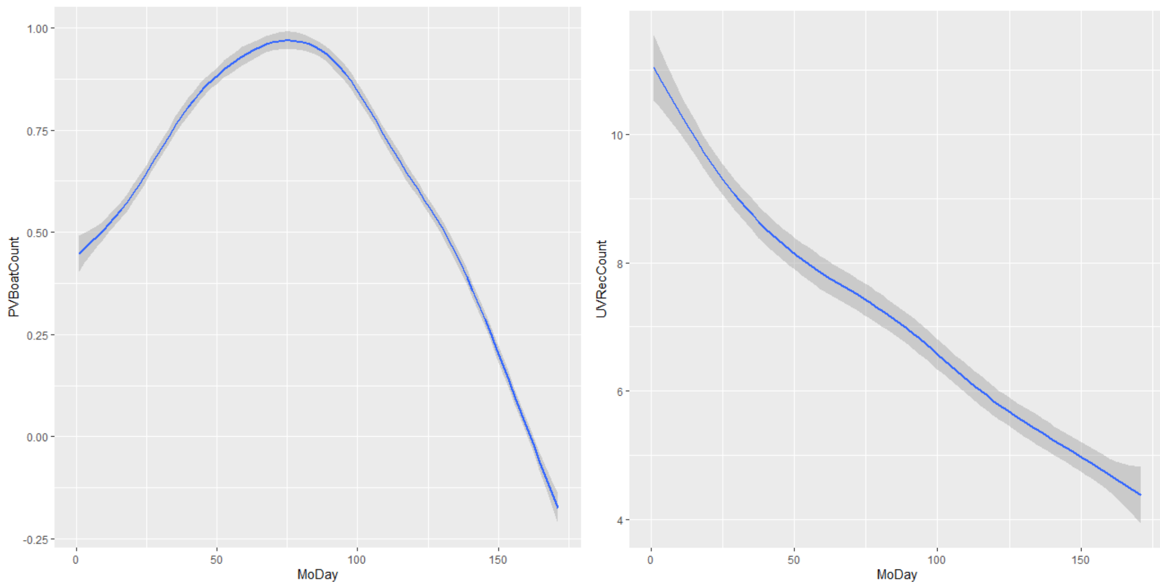


Figure 19. Seasonal trend in (a) mean daily boat visits and (b) mean daily total visits at **Finlay Bay** recreation site. Reservoir water level, weather, and day of the week were controlled as influences on mean daily boat visits and total site visits. This is a control site with no improvements during the 10 year (2009 – 2018) monitoring period.

Table 11. Generalized linear mixed effect models of season, reservoir water level, and weather influences on mean daily boat visits and total site visits at **Finlay Bay** recreation site (control site with no improvements).

	Boat Count (Photo Validated)		Site Use (Counter Events)	
Predictors	Estimate (IRR)	p	Estimate (IRR)	p
Intercept	-1.53 (0.22)	**<0.001**	-1.60 (4.96)	**<0.001**
Elevation	0.02 (1.02)	0.224	-0.05 (0.95)	**<0.001**
Temperature	0.08 (1.09)	**<0.001**	0.02 (1.02)	**<0.001**
Precipitation	0.001 (1.00)	0.915	-0.02 (0.99)	**0.008**
Wind Gust (Moderate)	-0.01 (0.99)	0.922	0.004 (1.00)	0.951
Wind Gust (High)	0.10 (1.11)	0.462	0.10 (1.10)	0.196
Weekend	0.13 (1.14)	0.189	0.51 (1.67)	**<0.001**
Random Effects				
σ^2	1.36		0.68	
τ_{00}	0.00 $_{\text{MoYear}}$		0.12 $_{\text{MoYear}}$	
ICC			0.15	
N	10 $_{\text{MoYear}}$		10 $_{\text{MoYear}}$	
Observations	1410		1505	
Marginal R^2 / Conditional R^2	0.111 / 0.245			

Site Use Characteristics (Recreation Site Use)

Number of Site Visits

Recreation site use (10 year averages) estimated from photo-validated counter data ranged from 358 total visits annually at Finlay Bay to 1,114 visits annually at Cut Thumb (**Table 12**).

Table 12. Estimated total visits (boaters and non-boater visits) by site during the 10-Year monitoring program (2009 - 2018). Parentheses indicate lower and upper estimates among sites[1]. Monitoring period: May 14 – October 31 annually.

Site	10-Year Average	Pre-Improvement	Post-Improvement
Cut Thumb Bay	1114 (947- 1565)	630 (445 - 1409)	1176 (1010 - 1649)
Six Mile Bay	466 (386- 731)	386 (288 - 659)	586 (534 - 840)
Finlay Bay	358 (289 - 480)	NA	NA
Elizabeth Creek	504 (408 - 986)	NA	NA
Dunlevy	860 (645 - 988) [2]	668 (435 - 886)	1099 (907 - 1116)
Mackenzie Landing	828 (685-1116) [3]	976 (752 - 1263)	738 (644-1028)

[1] Estimate = photo success as correction factor multiplied by minimum count. Minimum = photo validated visits = number of unique car ID (PVCarID). Maximum = all counter records without redundants (PVRecCount), divided by 2 for sites where monitoring equipment was on the access road or 4 where monitoring equipment was on the boat ramp.

[2] Dunlevy was monitored over 9 years: pre-improvement (~~2019~~ 2009 – 2013) and post-improvement (2015 – 2018).

[3] Mackenzie Landing was monitored over 8 years (2011 – 2018).

Number of Boat Visits

Recreation site use by boaters (10 year averages) ranged from 90 boat visits annually at Finlay Bay to 269 visits annually at Cut Thumb (**Table 13**). The highest numbers of boat visits annually were at Cut Thumb (351 boat visits on average annually) and Dunlevy (368 boat visits) post-improvement. The proportion (10 year averages) of photo-validated site users that brought boats varied from 28.3% at Mackenzie Landing to 60.4% at Elizabeth Creek (**Table 13**).

Table 13. Number of boat visits annually during the 10-Year (2009 - 2018) monitoring program. Parentheses indicate the proportion (%) of total photo-verified site users annually.

Site	10-Year Average	Pre-Improvement	Post-Improvement
Cut Thumb Bay	269 (33.3)	186 (42.3)	351 (24.3)
Six Mile Bay	111 (29.2)	87 (30.4)	146 (27.3)
Finlay Bay	90 (31.1)	NA	NA
Elizabeth Creek	251 (60.4)	NA	NA
Dunlevy[1]	237 (34.7)	132 (30.3)	368 (40.3)
Mackenzie Landing	192 (28.3)	151 (19.9)	217 (33.3)

Duration of Stay

For boaters, mean duration of stay (10 year average) ranged from 13.6 hrs at Mackenzie Landing to 64.5 hrs at Finlay Bay (**Table 14**). At all sites, mean duration of stay for boaters exceeded that for non-boaters.

Table 14. Mean duration of stay (hours with minimum to maximum range) for site users with or without boats at 6 recreation sites that provide access to Williston Reservoir.

Site	n	10-Year Average	Pre-Improvement	Post-Improvement
Dunlevy Boaters	1160	33.4 (0.002 – 1845.5)	28.7 (0.002 – 262.8)	34.5 (0.01 – 1845.5)
Non-Boaters	1232	3.6 (0.004 – 185.7)	8.8 (0.1 – 185.7)	2.1 (0.004 – 100.1)
Elizabeth Boaters	1901	26.6 (0.01 – 2784.7)	NA	NA
Non-Boaters	1210	1.37 (0.001 – 821.3)	NA	NA
Mackenzie Boaters	1371	13.6 (0.002 – 1940.5)	9.1 (0.002 – 216.9)	15.2 (0.01 – 1940.5)
Non-Boaters	3247	0.4 (0.001 – 214.6)	0.6 (0.001 – 214.6)	0.3 (0.001 – 94.7)
Cut Thumb Boaters	1747	37.1 (0.001 – 539.7)	22.4 (0.08 – 285.7)	39.6 (0.01 – 539.7)
Non-Boaters	3786	26.6 (0.003 – 960.3)	28.7 (0.04 – 236.0)	26.5 (0.003 – 960.3)
Six Mile Bay Boaters	770	33.6 (0.02 – 559.0)	24.2 (0.02 – 262.5)	41.8 (0.07 – 559.0)
Non-Boaters	1706	23.1 (0.02 – 2591.0)	11.5 (0.02 – 351.1)	31.1 (0.04 – 2591.0)
Finlay Bay Boaters	627	64.5 (0.07 – 366.5)	NA	NA
Non-Boaters	1207	23.6 (0.002 – 374.7)	NA	NA

Number of Repeat Visitors

The number of recognizable repeat visitors (10 year averages) per site ranged from 42 annually at Finlay Bay to 243 at Cut Thumb (**Table 15**).

Table 15. Number of ~~recognizable~~ easily recognized repeat visitors per site during the Year 9 (2017) monitoring period, May 14 – October 31.

Site	10-Year Average	Pre-Improvement	Post-Improvement
Cut Thumb Bay	243 (40 – 451)	60 (40 – 84)	390 (284 – 451)
Six Mile Bay	67 (28 – 135)	48 (28 – 89)	91 (70 – 135)
Finlay Bay	42 (11 – 89)	NA	NA
Elizabeth Creek	93 (35 – 146)	NA	NA
Dunlevy	97 (11 – 196)	41 (11 – 56)	153 (54 – 196)
Mackenzie Landing	151 (58 – 235)	170 (122 – 246)	140 (58 – 235)

DISCUSSION

Management Questions

Q1. Did recreational use of Williston Reservoir boat launches increase after boat access is improved?

Q2. Did seasonal use change with improved access during low reservoir levels?

The primary purpose of the monitoring program was to quantify a) changes in the number of recreational boaters and b) changes in the seasonal timing of recreational boating following improvements to boat ramps at selected sites on Williston Reservoir. Observed changes in boat visits at Dunlevy demonstrate the desired positive impact that ramp upgrade investments made in achieving the management goals.

At **Dunlevy**, boat ramp improvements resulted in an overall increase in boat visits (treatment effect suggests double (2.11 times) the visits post-improvement), and moderated the influence of reservoir elevation. Model results suggest that reservoir elevation is no longer a limiting factor for boater access at Dunlevy, and indicated a preference for early season use at this site. This was supported by the plot of boat visits as a quadratic function of monitoring day, which showed a shift in peak use from mid-season (Day 80; August 1st) before ramp improvements to early season (<Day 50; May 14 – July 1) after improvements.

At **Alexander Mackenzie Landing**, the strength of the monitoring program's ability to detect meaningful changes in site use after ramp improvement in 2014 was limited. There are 3 complimentary explanations for this. First, pre-improvement monitoring data were limited and may not have provided an adequate test of the importance of the low-elevation boat ramp. Mackenzie Landing was added to the monitoring program in 2011 (Year 3), an anomalous year with heavy rain that caused bank erosion and damage to the site access road. Although the site remained open to the public, poor weather combined with intermittent construction for road and bank maintenance through the spring and summer likely reduced site visits in spring 2011. In addition, 2011 is the only monitoring year at Mackenzie Landing where elevation was <658 masl (the height of the lower ramp), reaching 658 on May 23 (Monitoring Day 9). Reservoir levels are <658 masl for short periods in early spring and quickly reached >662 masl (the upper ramp) in pre-improvement monitoring years 2011-2013. In these years, boat access in early spring was not limited by reservoir elevation, which suggests no reason to expect a change in boat visits during the monitoring program as a result of improved access at low reservoir levels. The lower ramp is likely a more important resource for spring boaters in low water years like 2009 and 2010 (before monitoring started at this site). Second, given the close proximity to town and the shorter durations of stay, weather conditions may influence site visit decisions. Third, this site has a shallow shoreline gradient with a rudimentary road across the foreshore that makes the site amenable to boat launching even in the absence of constructed low-elevation ramps. It is possible that pre-and post-improvement site use represents baseline levels of boat visits annually regardless of reservoir elevation, with a preference for mid-season use of the site.

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Addendum to GMSMON-20: Williston Reservoir Recreation Use Monitoring Program Final Report, 2009 – 2018

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Disclaimer

Bradshaw Environmental Planning prepared this addendum at the request of BC Hydro. The material in it reflects the best judgement of Bradshaw Environmental Planning based on a review of the GMSMON-20 Final Report prepared by Cubberly and Hengeveld (2019). Please note that Bradshaw Environmental Planning did not conduct any secondary analyses of the data contained within Clubberly and Hengeveld (2019). Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, is the responsibility of such third parties. Bradshaw Environmental Planning accepts no responsibility for damages, if any, suffered by any third party because of decisions made or actions based on this report. Any reproductions of this report are uncontrolled and may not be the most recent revision.

Purpose

The purpose of this addendum is to provide further interpretation of the data presented in the report titled: *GMSMON-20 Williston Reservoir Recreation Use Monitoring Program Final Report, 2009 – 2018* prepared by Cubberly and Hengeveld (2019). Unfortunately, the consultants who prepared the original report are no longer available to re-analyse the data, thus necessitating this addendum.

Background

In March, 2023, BC Hydro received the report that summarized all the collected data for the monitoring project GMSMON-20: Reservoir Recreation Use. The final report provided answers to the management questions (MQs) from BC Hydro's Terms of Reference for GMSMON-20 (BC Hydro, 2008). The answers to the MQs were based on statistical analyses of monitoring data collected from 2009 – 2018 by Synergy Applied Ecology. The analyses focused on changes in the number, timing, and frequency of boat visits and boat launches to recreation sites that provide access to Williston Reservoir.

Organization of this Addendum

The Addendum is organized as follows:

Section 1: Management Questions and Impact Hypotheses for GMSMON-20
Section 2: Potential issues with the GMSMON-20 Final Report
Section 3: Further interpretation of the answers to the management questions

1. Introduction

The purpose of the GMSMON-20: Reservoir Recreation Use study is to answer two management questions by testing two impact hypotheses.

The management questions (MQs) are:

1. Does the recreational use of the Williston Reservoir boat ramps increase after boat access has been improved?
2. What is the frequency of use of newly constructed boat ramps?

The impact hypotheses (IHs) are:

H1: Recreational use of boat ramps has increased following improvements to boat access.

H2: Timing (e.g., by month) of boating parties for recreational activities changes following improvements to boat access.

Experimental design, project background, and other related information is contained in Cubberly and Hegenveld (2019). In short, the MQs and IHs were designed to test if newly constructed boat launches on the Williston Reservoir increase recreation use and if the new launches shifted the timing of when recreationists use the reservoir.

The primary finding from Cubberley and Hengeveld (2019) is:

"*Observed changes in boat visits at Dunlevy demonstrate the desired positive impact that ramp upgrade investments made in achieving the management goals.*" (p.ii, Cubberly and Hengeveld, 2019)

The authors base their primary finding from answers to the Impact Hypotheses written below.

H1: *"Recreational use increased at Dunlevy in response to greater boat access opportunities provided by ramp improvements. There was no change in recreational use at Mackenzie Landing in response to boat ramp improvements."* (p.iii, Cubberly and Hengeveld, 2019)

H2: "*Peak boat visits at Dunlevy shifted from mid-season (Day 80; August 1st) before ramp improvements to early season (<Day 50; May 14 – July 1) after improvements. There was no significant difference in the timing of peak boat visits at Mackenzie Landing before and after ramp improvements."* (p.iii, Cubberly and Hengeveld, 2019)

While Dunlevy saw in increase in the number of boats launched post-construction, enough evidence exists in the GMSMON-20 Final Report and other BC Hydro reports to suggest that ramp upgrades may not be responsible for increasing the number of boats launched (i.e., a proxy for recreation use). The evidence is presented in the following section.

2. Potential Issues with the GMSMON-20 Final Report

Two issues exist with the GMSMON-20 Final Report that warrant further examination: the use of Elizabeth Creek as a control site, and the cleaning of the data set. Both issues are described below.

Elizabeth Creek as a Control Site

Evidence suggests that Elizabeth Creek (EC) is not a suitable control site. Since 2011 (Year 4), access to EC across the dam required passing through a security check point with personal identification required. Also, construction and spilling at the dam further restricted access to EC throughout the monitoring period (see GMSMON-20 Final Report for details). A reasonable assumption is that this restriction in access to EC negatively affected use at the site.

From the report, mean daily boat count and total site visits declined by 4% and 6% respectively at the control sites (i.e., EC and Finlay Bay combined). However, examination of the two control sites shows that EC is driving this decline because use at Finlay Bay increased over the ten-year period. Removing EC from the control data and reanalyzing the control versus treatment sites should provide a better representation of how use at an 'untreated' site compares to 'treated' sites. If this action is taken, then it may be reasonable to expect that treatment sites show little change in use relative to the control.

Data cleaning

On November 23, 2023, StatMathComp Consulting examined and provided an overview of the issues associated with the data for the GMSMON-20 monitoring project. The GMSMON-20 database consists of a mixture of excel spreadsheets, access databases, raw images, and GIS data. Data include a large number of photos of vehicles entering and exiting the survey sites. A substantial reorganization and reconciliation of these databases and photos would be required to perform any further analyses for this study.

However, before any data cleaning occurs, we may already have enough information to answer the management questions (as discussed in the next section).

3. Further Interpretation of Management Question Answers

The available evidence suggests that building boat launches does not increase recreation use.

BC Hydro implemented two boat launch improvement studies (i.e., CLBMON-14 and GMSMON-20) to measure the change in use of boat launches after upgrades to the ramps were completed. The study design for CLBMON-14 was similar to GMSMON-20. CLBMON-14 used a Before, After, Control, Impact (BACI) experimental design by monitor the use of boat launches both pre and post boat launch upgrades in the Columbia River system using vehicle counters located at ramp study sites (see Lees and Associates, 2021 for a full explanation). One common hypothesis for the two boat launch improvement studies (i.e., CLBMON-14 and GMSMON-20) is that improvements will increase the number of boats launched. However, the weight of evidence suggests that upgrading boat launches does not result in more boats launched.

In both the Columbia and Peace systems combined, 10 boat launches were improved that had pre and post construction data[1]. Only 2 launches saw an increase in use post-construction (i.e., Dunlevy and McDonald Creek). For the remaining 8 eight boat launches, 3 sites saw a decrease in use (i.e., Nakusp, Fauquier, and Anderson) and 5 sites saw no change in use (i.e., Mackenzie, Shelter Bay, Syringa,

[1] BC Hydro improved 12 sites in total, but 2 sites did not have pre-construction data (i.e., Bush Harbour and Burton).

Valemount, Edgewood)[2]. However, as noted in the CLBMON-14 report, " … *a simple before-after comparison may show an effect that is due to general temporal changes rather than an impact of construction*." (p.29, Lees and Associates, 2021).

A more refined analysis for the CLBMON-14 boat launches was conducted that controlled for general temporal trends (appendix G, Lees and Associates, 2021). Using the Burton Historic boat launch as a control site for the Arrow Lakes boat launches, no sites showed a statistically significant increase in boat launches post-construction. In other words, the increase in use at McDonald Creek when comparing pre and post construction data is no different from general temporal changes when compared to the Burton Historic control site.

Although Dunlevy shows an increase in use when comparing pre and post construction data, we cannot rule out the possibility that the increase in use we see at Dunlevy is due to general temporal increases in the area. We cannot rule out that possibility because we cannot rely on Elizabeth Creek as a control site[3] to determine if this increase in use runs contrary to general temporal changes.

A better performance measure for the efficacy of boat launch upgrades is 'safe-access-days'.

Although we cannot rule out a change at Dunlevy from a general temporal change, one potential explanation for the observed increase in use at Dunlevy is the fixing of a safety issue. Before the upgrades at Dunlevy, launching a boat at Dunlevy at elevations less than 667 masl was dangerous because of conditions at the toe of the ramp[4]. In 2015, the toe of the ramp was extended from 667 masl to 660.5 masl, thus allowing boaters to launch at elevations lower than 667 masl.

On Williston, water elevations usually reach 667 masl and above starting in May/June of each year with some exceptions (see figure 3, Cubberly and Hengeveld, 2019). In other words, the increase in use at Dunlevy might be boaters being able to access the reservoir during the spring time when historical access at this time of the year was dangerous. This potential explanation is supported by the observation that spring time use of the Dunlevy ramp is substantially higher after the toe was extended (see Figure 9, Cubberly and Hengeveld, 2019). Unfortunately, we do not have the necessary conditions at other ramps to test if fixing potential safety issues (i.e., inability to launch at certain elevations) explains an increase in use.

In light of the information above, a better proxy for BC Hydro in future upgrade decisions may be to examine the number of days that recreationists can safely access a reservoir at a given site (i.e., safe-access-days) and how upgrades will change that measure. The experience at Dunlevy combined with the lack of a relationship between boat launch upgrades and increased use at the other sites, provides some support for the use of 'safe-access-days' as opposed to 'increased-use' as a metric for measuring the efficacy of boat launch upgrades.

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[2] In the CLBMON-14 report (Lees and Associates, 2021), written results presented on p.29 differ from results presented in Table 9, p.31. Instead of 3 ramps that had a decline in use post-construction, table 9 shows 5 ramps with a decline in use post-construction. This difference only reinforces the fact that a relationship between site improvements and increase in boat launch use should be rejected.

[3] Finlay Bay is the other control site for Williston; however, comparing Dunlevy with Finlay Bay was not done.

[4] Based on my knowledge of the area and file photos of the ramp prior to construction.

If increases in recreation use is the preferred proxy for measuring upgrade effectiveness, then BC Hydro has more alternatives available to them than just building boat launches.

The Water Use Plan Consultative Committees viewed the improvements of boat launches as a positive step for increasing recreation use in the area. If BC Hydro wants to increase recreation use then they could explore partnering with other land managers and upgrading the surrounding recreation assets. Evidence from Cut-Thumb and Six Mile as presented in the GMSMON-20 report suggests that campsite improvements can generate increases in boat-visits when compared to boat launch improvements. Partnering with other land managers could help to remove BC Hydro from managing recreation assets. However, recreation use is dependent on many factors outside the control of BC Hydro or other land manager (e.g., weather, condition of access roads, crowding effects, etc.).

4. References

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