Bridge River Project Water Use Plan

Lower Bridge River Spiritual and Cultural Value Monitoring

Implementation Year 3

Reference: BRGMON-16

Study Period: August 2015 – June 2016

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BRGMON-16 STATUS of OBJECTIVES, MANAGEMENT QUESTIONS and HYPOTHESES after Year 3

Study Objectives	Management Questions	Management Hypotheses	Year 3 (2015-2016) Status
Collect information needed on the smell, sound, movement and interaction of people and water of the Lower Bridge River under the 6 cms/y flow regime and use this information to evaluate the cultural and spiritual objective that was discussed in the Consultative Committee process.	How does the smell, sound, movement and interaction (of people and water) on the Lower Bridge River under the 6 cms/y flow regime compare with that in the Yalakom River, an adjacent unregulated tributary of the Lower Bridge River?	The smell, sound, movement and interaction (of people and water) on the Lower Bridge River under the 6 cms/y flow regime does not differ from the Yalakom River.	There are higher spiritual and cultural values in the Yalakom in comparison to the LBR. The study is on track for strengthening the conclusion for the management question in Year 5 using the current approach/study design. Results contributed to the preliminary conclusion that the spiritual and cultural values are insensitive to water flow levels which is demonstrated by the relatively little to no change in the Spiritual and Cultural scores over a large range of discharges.

Executive Summary

The BRGMON-16 Water Use Plan (WUP) monitoring project is being undertaken by BC Hydro and St'át'imc Eco-Resources to measure and monitor a set of cultural and spiritual attributes in relation to different flow discharges in the Lower Bridge River (LBR) below Terzhagi Dam. The information is needed to incorporate non-tangible inputs into a future long-term flow decision for the LBR. During Year 3 of the project between six and eight St'át'imc elders participated as evaluators to score their perceptions of cultural and spiritual values at different water flow discharges ranging between 7.8 cubic meters per second (cms) in August 2015, 1.5 cms in October 2015, 3.1 cms in March 2016 and 96 cms in June, 2016. The Yalakom River was adopted as an adjacent (unregulated) control river and four seasonal surveys were simultaneously conducted in the LBR and the Yalakom. A total of 9 variables were evaluated at 10 sites with a scoring system that ranged between 0 (least favorable) and 4 (most favorable).

The 9 variables were analyzed 1) statistically using General Linear Interactive Modeling (GLIM) 2) graphically by histogram analysis and 3) by directly evaluating relationships between flow discharge and spiritual/cultural parameters. Modestly higher parameter scores were obtained in the Yalakom demonstrating that this river is perceived by St'át'imc elders to provide higher spiritual and cultural values than the LBR. This conclusion should be interpreted with caution as the elders were aware that the LBR is regulated whereas the Yalakom River is not. Counter intuitively, results indicated little variation in the parameter scores across different seasons, thereby allowing direct analysis of the effects of flow discharge in the absence of seasonally confounding effects. Analyses indicated that in spite of the large variations in flow conditions, which ranged in the LBR between 1.5 cms and 96 cms, there was little variation in parameter scores. Scatter plots suggested the nine variables appeared to be insensitive to flow discharge variations in the LBR for the range of flows that were examined.

Contents

Introduction

Year 3 of the BRGMON-16 monitoring project was undertaken between August 10, 2015 and June 2, 2016 to monitor some of the intangible but culturally significant attributes of different flows in the Lower Bridge River and their influence on peoples' perceptions of river health. This work was designed to assess the influence of flow changes associated with the Water Use Plan (WUP) on biological components and human perceptions of the ecosystem (this project).

The structured decision-making framework developed by Compass Resource Management Ltd. and the former Bridge River Technical Working Group (TWG) addressed 9 different objectives or endpoints. Eight of these - salmon, river health, riparian health, riverine birds, species of concern, financial impacts, learning, and stewardship – were measurable via empirical data or through judgments from members of the TWG (e.g., assessments of learning associated with different flows). The spiritual and cultural objective, concerned with changes in the smell, sound, movement, and interaction associated with different flows of water in the Lower Bridge River, is expressed through scales for which input is obtained only from members of the St'át'imc community. This report describes the third year of a project that St'át'imc Eco Resources undertook on behalf of BC Hydro to monitor the impact of changing Bridge River flows on spiritual and cultural values. Unlike the original project design developed by the WUP Consultative Committee in the early 2000's which involved comparative observations under 0, 3 and 6 cms Lower Bridge River hydrographs, flow discharge conditions at the start-up of the project only covered 6 cms rendering the original project design inapplicable. Instead, the project was modified to include comparative observations from the Yalakom River, a tributary of the Lower Bridge River with similar flow characteristics.

During 2016 there was a requirement to spill excess water down the Lower Bridge River because of the reduced capacity to pass flows into Seton Lake via the Bridge 1 and Bridge 2 Generating Stations due to their de-rated generator units. Flow discharges of 96 cms occurred during the June, 2016. The high flows are presently being managed by BC Hydro and the St'át'imc and will likely occur in future years. For the BRGMON-16 project, Survey 4 which coincided with the June'16 survey provided a unique opportunity to gauge the perceptions of the elders to the unusually high flow conditions.

Background

The Bridge-Seton Consultative Committee (BRG WUP CC) and more recently the Bridge River Technical Working Group recommended that as part of the Water Use Plan the current flow testing program now underway at Terzaghi Dam be continued and expanded from an average of 3 cms/y to a second flow level (6 cms) to empirically document the response of the ecosystem to instream flow changes in Lower Bridge River. A long term test flow release program was recommended with monitoring programs to empirically measure the environmental benefits that could arise from two alternative instream flow release regimes considered by the Bridge River Technical Working Group. The flow regimes differ in the relative shape of the delivered hydrograph and the annual water budget delivered (referred to as: 3 cms/y, 6 cms/y treatments). The 3 cms/y treatment occurred from August 2000 to April 2011, and the 6 cms/y treatment started in May 2011. While daily and monthly discharges differed from one another, the annual discharge averaged 6cms.

St'át'imc elders speak of the "spirit" or "voice" of the Lower Bridge River. They have observed that in moving from a water budget of 0 to 3 cms/y there were noticeable improvements in conditions for tangible outcomes like fish, wildlife, and riparian vegetation. But in addition, and distinct from these, there have been improvements in the "spirit" or "voice" of the river. Across the range of proposed flows (including a doubling of the average flows, from 3 cms/y to 6 cms/y), it was anticipated that there is potential for additional beneficial change to these important spiritual and cultural values.

To obtain information to better define the spiritual and cultural objective, during the TWG review process, input was collected from interviews with St'át'imc Technical Working Group members, from discussions with other members of the St'át'imc community, and from a workshop held in Lillooet in the mid-2000's to hear the views of invited St'át'imc elders and other individuals familiar with the river. From these meetings, four key qualitative components of cultural and spiritual quality were defined:

Sound:

- The voice of the water (a variable defined by the observers individually)
- Birdsong (an integration of songbird presence)

Smell:

- The smell of the river itself (as determined by the observers individually)[2]
- The ambient smell at water's edge (as determined by the observers individually)

Movement:

- Movement of water (seasonally appropriate)
- Diversity of movement (pools/riffles)

[2] as measured at approximately 10 m from the water's edge

Interaction (of people and water):

- Shore access (ability to easily walk to the shoreline)
- “Wade-ability” (the ability to walk in and/or across the river at certain locations)

Prior to the initiation of the first session of field work in the summer of 2013, a 9th variable, Water Clarity, was added to the survey.

These nine components clearly do not provide a universal definition of cultural or spiritual quality. They define aspects of cultural and spiritual quality believed to be relevant for the evaluation by St’át’imc elders of alternative flow regimes on the Lower Bridge River, within the (average annual) range of 0 to 6 cms/y. The information on spiritual and cultural values will provide an important measure that will be integrated with other social and environmental measures in an overall evaluation of the 6 cms/y flow regime.

The Yalakom River has been described by Komori (1997; p.14):

> "The Yalakom is 56 km in length and provides the majority of accessible stream length for salmonids within the Bridge River system....the stream gradient in the Yalakom is generally very steep, averaging 2.5% over the 15 km most commonly utilized by anadromous salmonids below the partial barrier. The typical annual hydrograph closely follows the cycle of highland snowmelt runoff causing water temperatures to be lower than the regional averages. Discharge in the Yalakom River varies from 1.4 to 28.1 cms. The torrential nature of this stream, low average temperatures and limited fish habitat reduces the production potential in the Yalakom River"

The Bridge River originates in the ice fields of the Coast Mountains and flows east for 154 km before entering into the Fraser River 5 km north of Lillooet. The Lower Bridge River is confined to a narrow valley downstream on Terzhagi Dam, partly cut in bedrock but often incised into glacio-lacustrine and glacio-fluvial deposits (Komori 1997). The Lower Bridge River floodplain was shaped by historical (pre-impoundment) flow levels of approximately 100 cms/year on average, and ranging as high as 700 cms during former freshet periods (Golder 1999). Thus the present-day flows represent approximately 3-6% of the former mean annual discharge. When compared with the Yalakom, the Lower Bridge River has a relatively broad flood plain reflecting the pre-impoundment flow discharges that were an order of magnitude larger than presently.

Relevant Literature

There are a few examples of projects which have integrated spiritual and cultural values in water resource management, notably in Australia (Collings 2012). The latter study presents the results of 6 pilot projects involving spiritual and cultural value components (Table 1). The focus of these projects is integration, while the focus of BRGMON 16 is on the measurement of variables which were selected due to their close alignment with spiritual and cultural values. Overall Collings (2012) concluded:

> *"Integrating the cultural and spiritual values of Indigenous people into water quality management requires careful and considered planning and follow-up, as well as due respect for Indigenous law, custom and traditional knowledge."*

Econometric approaches to the valuation of ecosystem services in river basins (Loomis et al. 2000) rely on "willingness to pay" interviews with local residents as a means for estimating resource values. The main methodological approach involves interviews with local stakeholders (Clain et al. 2014) and providing a monetary equivalent for the ecosystem good or service that is being studied. For the BRGMON-16 study, the monetization of spiritual and cultural values is not applicable and such considerations are not within the realm of the St'át'imc world view. Satterfield et al. (2013) concluded that:

> *"Characterization of cultural benefits and impacts is least amenable to methodological solution when prevailing worldviews contain elements fundamentally at odds with efforts to quantify benefits/impacts, but that even in such cases some improvements are achievable if decision-makers are flexible regarding processes for consultation with community members and how quantification is structured."*

Table 1. Key findings from Australian case studies undertaken to integrate spiritual and cultural values into water quality management. Source: Collings (2012)

Case Study	Key Findings
Adelaide Coastal Water Quality Improvement Plan, South Australia	During the development phase of the draft ACWQIP, the South Australia EPA reports that stakeholders have been generally satisfied with the consultation and engagement processes. A key lesson is to ensure early engagement with Kaurna People to help achieve effective outcomes. The correct people need to be identified from the outset of such processes.
Police Lagoons Conceptual Model, Queensland	The conceptual models for Police Lagoons integrate science with cultural, spiritual and ecological values in order to inform integrated natural resource management of the lagoons. The objective is to support community goals to maintain and improve the wetland's values.
Engaging with and incorporating the views of the Queensland Far South West Aboriginal Natural Resource Management Group in water quality management planning, Queensland	The Far South West Aboriginal Natural Resource Management Group's values for the waters within the region will be incorporated into the future statutory environmental values and water quality objectives for the waters of south west Queensland under the *Environmental Protection (Water) Policy 2009*. The establishment of water quality objectives to protect aquatic ecosystem values is considered to generally afford protection of the cultural and spiritual values for the waters of the region.
Prioritising rock-holes of aboriginal and ecological significance in the Gawler Ranges, South Australia	One of the lessons learnt is that for projects like this, with a range of stakeholders from diverse backgrounds, it is very important to develop, implement and maintain a comprehensive communication/stakeholder engagement strategy prior to project initiation that continues throughout the project including follow-up.
Recognising indigenous cultural and spiritual values in maintaining river health of the Daly River, Northern Territory	Indigenous people possess intimate knowledge of their local environment and have complex value systems in connection with water and biodiversity. This knowledge is integral to holistic management planning to maintain river and ecosystem health.
Kungun Ngarrindjeri Yunnan (KNY) engagement with natural resource management	Protocols of engagement provide an important framework to recognise the values and status of Indigenous people in managing natural resources. The KNY Agreement provides a framework to assist and guide interactions with Ngarrindjeri people and for the most culturally appropriate and sensitive way of doing business on Ngarrindjeri traditional lands and waters.

Objectives and Scope

The original objective of this program, (presently inapplicable due to present and future spilling requirements) was to collect the information on the smell, sound, movement and interaction of people and water of the Lower Bridge River under a 6 cms/y flow regime and to use this information to evaluate the cultural and spiritual objective. While this management question remains relevant, and opportunity arose in 2016 to additionally evaluate how the smell, sound, movement and interaction (of people and water) in the LBR varies as a function of flow discharge.The objective of this program is to collect the information needed on the smell, sound, movement and interaction of people and water of the Lower Bridge River under the 6 cms/y flow regime and to use this information to evaluate the cultural and spiritual objective that was discussed in the Consultative Committee process.

Management Questions

The primary management question that being addressed by this monitoring program is:

> *How does the smell, sound, movement and interaction (of people and water) on the Lower Bridge River under the 6 cms/y flow regime compare with that in the Yalakom River, an adjacent unregulated tributary of the Lower Bridge River?*

Hypotheses Tested by the Monitoring

The primary management question will be tested using the following hypothesis:

> *H_O: The smell, sound, movement and interaction (of people and water) on the Lower Bridge River under the 6 cms/y flow regime does not differ from the Yalakom River.*

Key Water Use Decision Affected

The key water use decision affected by this monitoring program is the long term flow regime for the Lower Bridge River. Information from BRGMON 16 monitoring program will be used along with other performance measures to evaluate the 6 cms/y flow regime. Note that this water use decision will be deferred in view of current water management considerations within the Bridge - Seton system.

Study Area

The Study Area for this project extends between Terzhagi Dam and the Bridge River/Fraser River confluence. Consistent with the other WUP monitoring projects on the Lower Bridge

River, the Study Area was divided into 4 reaches utilizing existing reach boundaries. Reaches 2, 3 and 4 were analyzed (Figure 1) consistent with the Terms of Reference for BRGMON 16. Reach 1 was excluded from the analysis since the effect of the Terzhagi Dam release attenuates in a downstream direction due to increasing influence of groundwater inflows coupled with the combined Lower Bridge River tributary inputs. Several other monitoring studies (e.g. BRGMON 1: Lower Bridge River Aquatic Monitoring) have also focused exclusively on Reaches 2, 3 and 4 due to the attenuation of Terzhagi Dam flow release effects in a downstream direction from the Dam.

Reach boundaries of the Lower Bridge River and the locations of the sampling sites are shown in the map below. There were 6 observation sites in the Lower Bridge River (B1 - B6) and 4 observation sites in the Yalakom River (Y1 - Y4). Specific site locations were selected based on ease of access within reaches in order to maintain safe operating procedures and low risk of falling/injury.

The annual hydrographs for the two study rivers are shown in Figure 2. The net effect of the additional water releases was to increase the mean annual discharge from 6 cms to 25.7 cms (Calender Year from Jan. 1'15 to Dec. 31'15).

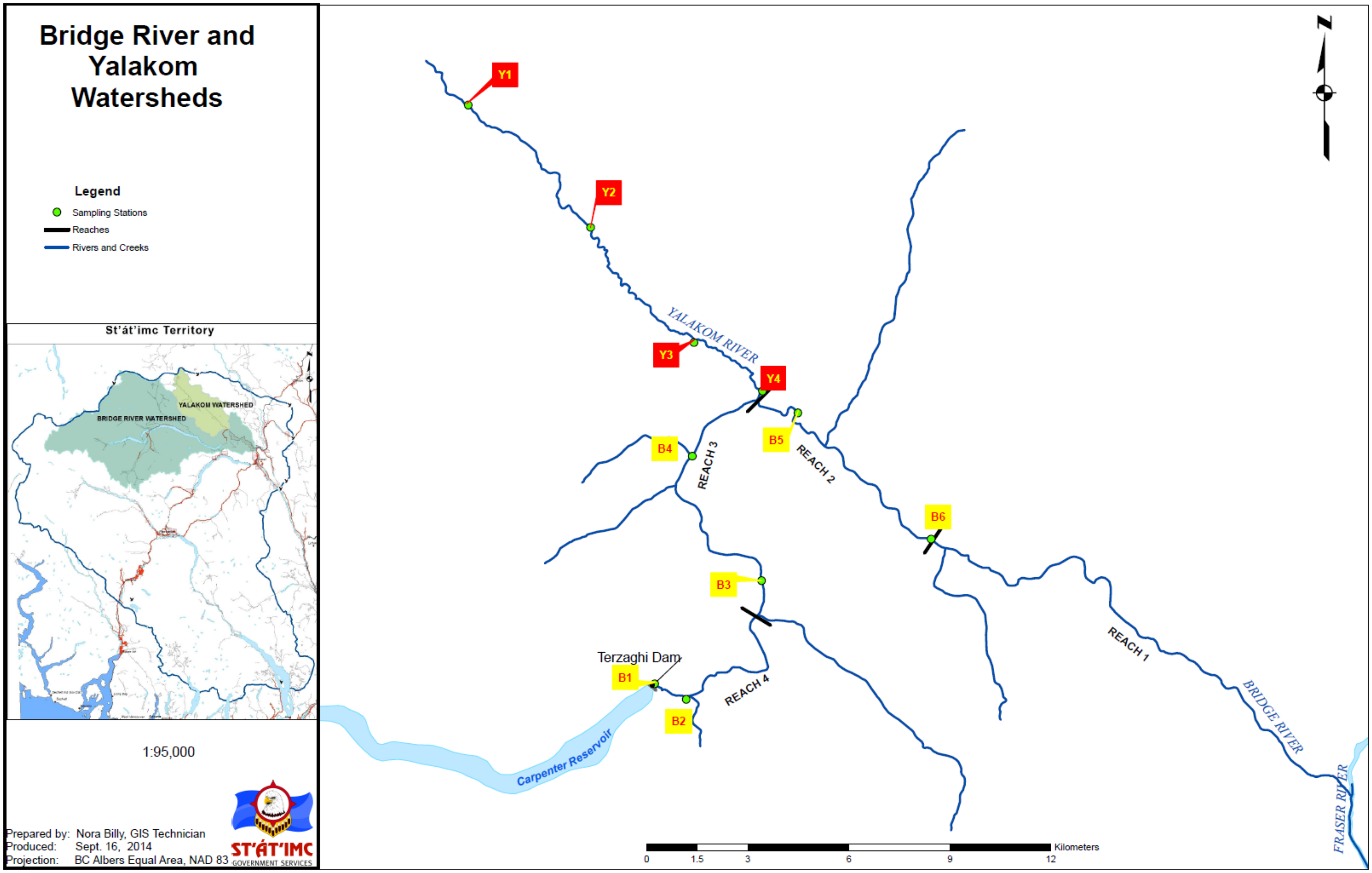

Figure 1. Location of sampling sites in the Yalakom and Lower Bridge Rivers.

The hydrograph for the Yalakom River (Figure 2) based on averaged Water Survey of Canada data for the period 1981 - 1990 (Station 08ME025) is shown in relation to the target flows for the Lower Bridge River under 3 cms and 6 cms discharges. The Yalakom River data were collected as part of a hydrology and water use investigation in the Bridge Seton Watershed (Rood and Hamilton 1995) that was commissioned Fisheries and Oceans Canada (DFO) during Fraser River Action Plan investigations. The Lower Bridge River flow discharges for 2013 - 2015 (Figure 3) were obtained from BC Hydro records. The selection of the Yalakom River as an unregulated control river for conditions in the Lower Bridge River was predicated on the occurrence of similar hydrographs in the two systems (Figure 2).

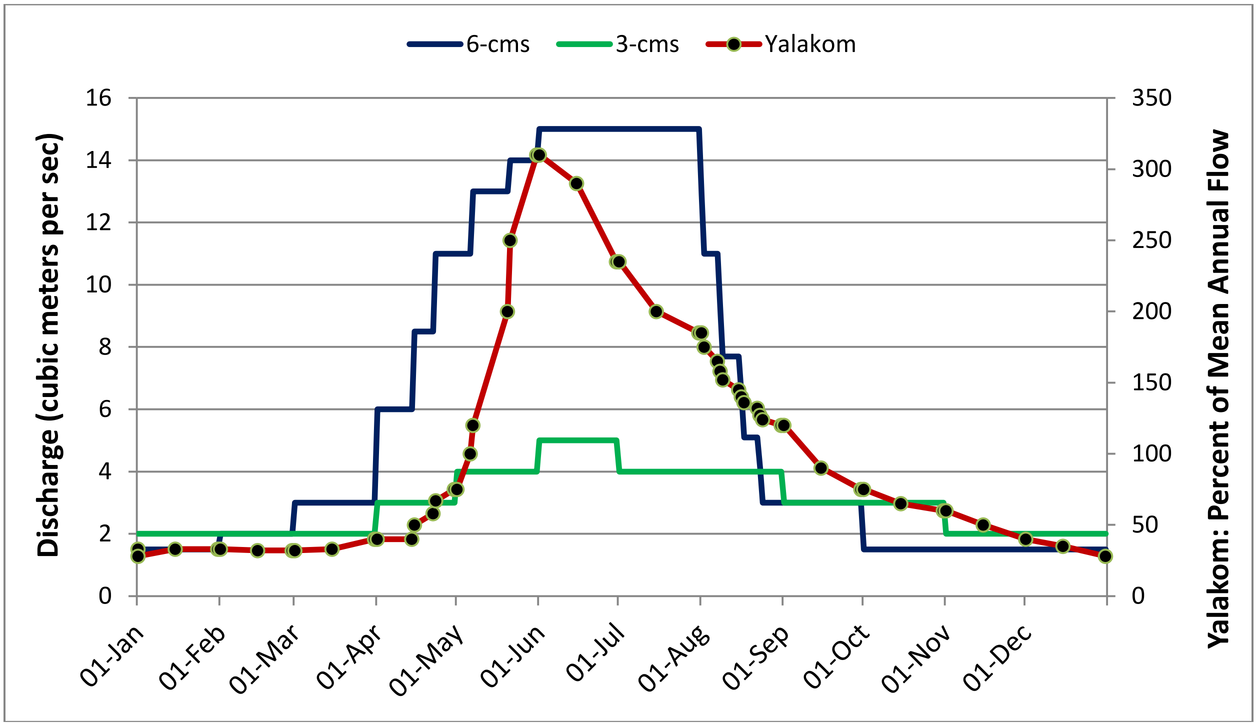

Figure 2. Comparison of Lower Bridge River flow discharges at 3 cms and 6 cms (annualized mean flow) in relation to averaged Water Survey of Canada data for the period 1981 - 1990 (Rood and Hamilton 1995). The annual mean Yalakom flow over this period was 4.11 cms.

The Lower Bridge River hydrographs (Figure 3) show the idealized flow discharges as agreed upon with the BC Comptroller of Water Rights in relation to actual flows between 2013 - 2015. Actual flows didn't depart significantly from the idealized target flows over the period of BRGMON 16 data collection between July 31, 2013 and March 7, 2015.

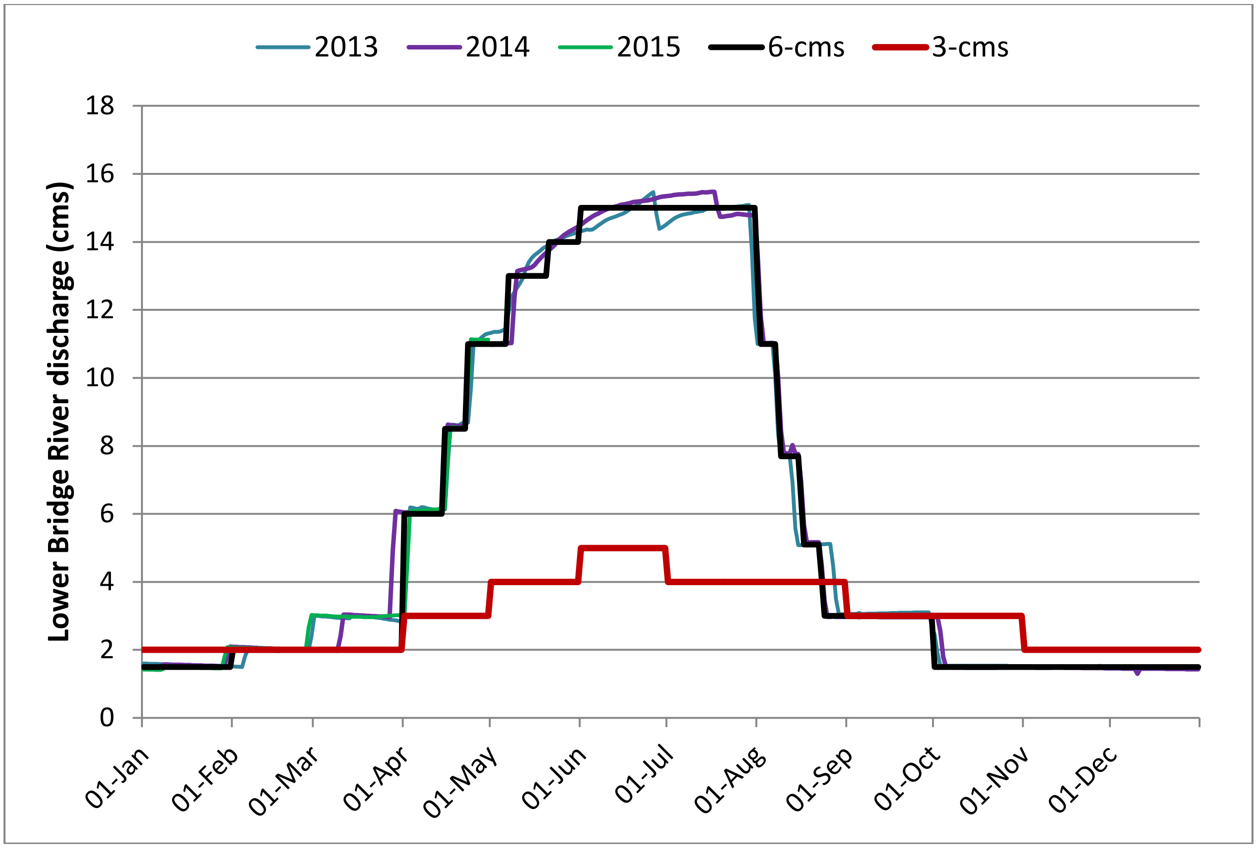

Figure 3. Actual flow discharges in the Lower Bridge River between 2013 - 2015. Flow discharge data provided by BC Hydro, Power Records.

As mentioned in the Introduction there was a need to spill excess water into the Lower Bridge River in 2016 that reached a peak of 96 cms in early June (see cover photo). Hydrographs depicting the discharge over the entire BRGMON 16 study period, including 2016, are shown in Figures 4 and 5.

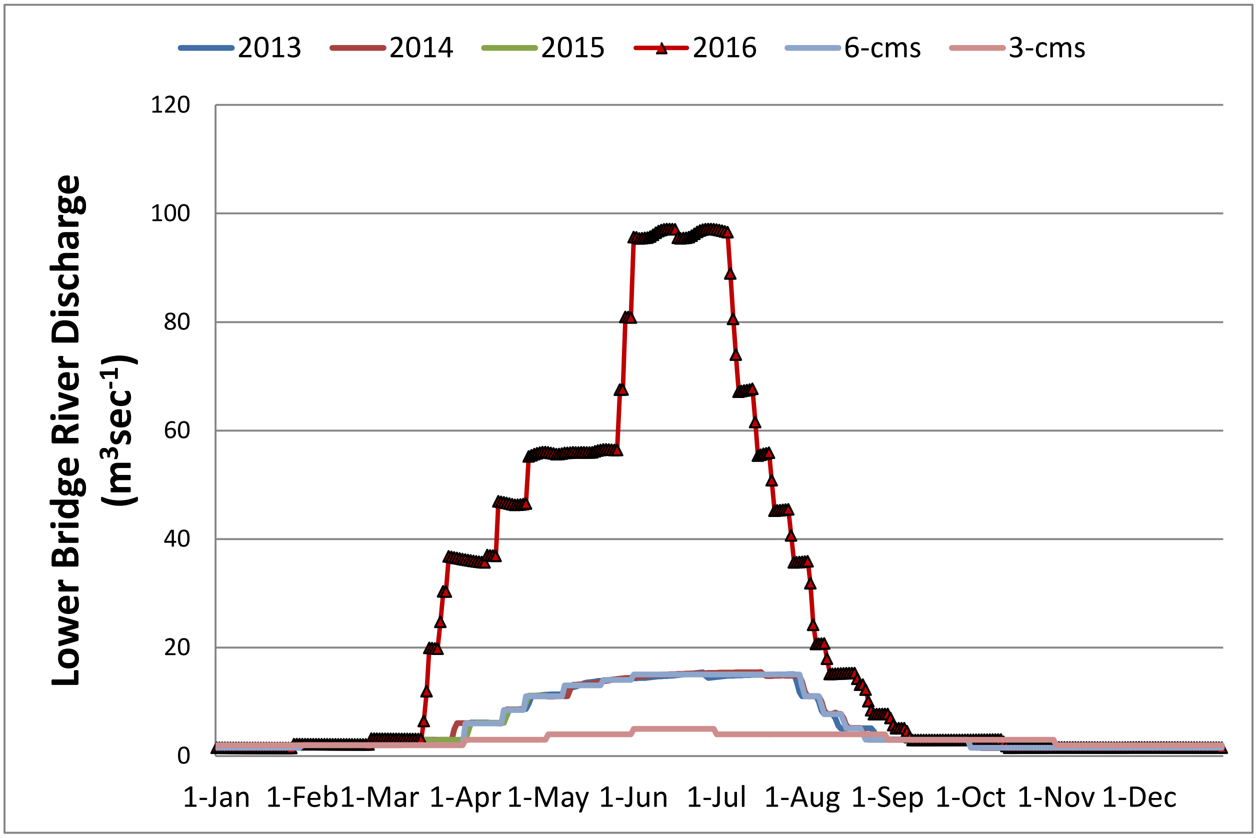

Figure 4. Flow discharge in the Lower Bridge River in 2016 in comparison with previous years. Flow discharge data provided by BC Hydro, Power Records.

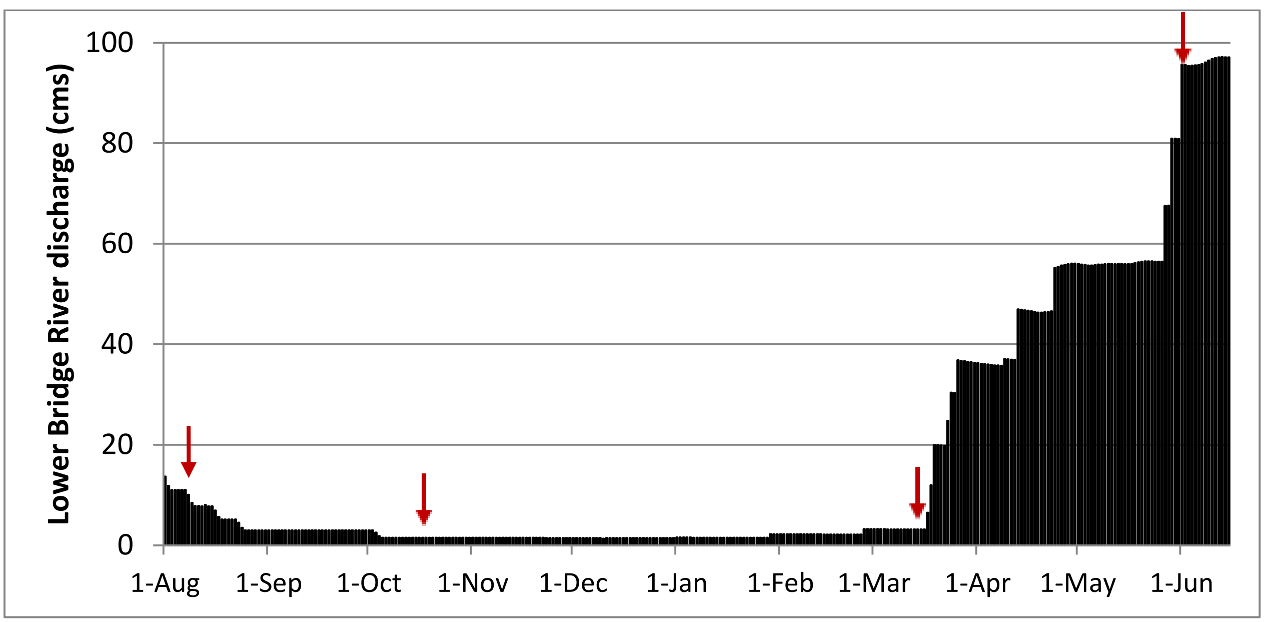

Figure 5. Flow discharge during Year 3 of the BRGMON 16 project. Flow discharges during the LBR survey dates (Aug. 10'15, Oct. 14'15, March 14'16 and June 1'16) are depicted by the red arrows.

Approach and Methods

To maintain consistency and transparency in assessment, a ***Cultural and Spiritual Quality Scale*** and a protocol for measuring it was utilized. The approach involved:

1. Six to nime St'át'imc elders who acted as observers; Continuity in membership was maintained so that consistency in the conduct of measurements was achieved.
2. Observations taken four times per year under a range of flows; : September (low flows, spawning fish present), March (low flows, winter conditions), April (moderate flows, spring conditions), June (peak flows, summer conditions, relatively low fish abundance/visibility). Sampling dates were replicated between years, with minor variations due to logistical constraints.
3. Observations taken at two Lower Bridge River sites per reach over reaches 4, 3 and 2;
4. Observations taken at four Yalakom River sites;
5. A simple and transparent scoring system for assigning scores to each component in each reach. On the designated date and site, each observer assigned a score of 0 to 4 for each of the four components (sound, smell, movement, interaction as well as water clarity), where 0 = low quality, 1 = moderately low quality, 2 = moderate quality, 3 = moderately high quality and 4 = high quality;
6. Analysis of aggregate scores across observers, components, reaches and seasons; and,
7. Statistical evaluation of results using a General Linear Interactive Model.

Anticipating that the elders would be unfamiliar with the adopted scoring system, the method was calibrated during a classroom session prior to the first field trip in 2013. During the session, elders scored their preference for 3 flavors of potato chips - salt and vinegar, barbeque and regular - according to the 0-4 scoring system above. Results demonstrated clear preferences for different chip flavours with barbeque rated highest preference with salt and vinegar lowest. The exercise reinforced the elders understanding of the method for scoring the spiritual and cultural variables.

Collected data were subjected to two different methods of analysis: 1) a graphical analysis by plotting histograms that displayed the mean and standard deviations of the spiritual and cultural attribute scores, and 2) General Linear Interactive Modeling (GLIM) a statistical software program for fitting generalized linear models (GLMs). It was advantageous to apply two independent analytical procedures to the BRGMON 16 data set to understand the areas of convergence and divergence between the two methods.

The GLIM procedure involved the following steps. First, the model with all fixed effects of interest, including interactions, was fitted to the data. Next, the least significant interaction was removed and the model was refit to the data. Lastly, the preceding step was repeated until the model only contained significant interactions and main effects (note that non-significant main effects were retained in models where they were part of a significant interaction).

Schedule

The Terms of Reference for the project indicated September (low flows, spawning fish present), February (low flows, winter conditions), April (moderate flows, spring conditions), and June (peak flows, summer conditions, relatively low fish abundance/visibility) as the preferred sampling dates. The actual scheduled surveys during 2015-2016 were Aug. 10-11'15, Oct. 14-15'15, March 14-15'16 and June 1-2'16. The timing of the surveys relative to the Lower Bridge River hydrograph, is shown on Figure 5. Minor departures from the TOR schedule were unavoidable due to logistical constraints, however, the deviations were small and observations during 2015-2016 covered a wide range of flow conditions. As discussed below, the scheduling deviations were informative by generating contrast in flow variations in the data set.

The surveys included the following flow conditions:

	Lower Bridge River Flow	Approximate Yalakom Flow[3]
August 10-11'15	7.8	7
October 14-15'15	1.5	3
March 14-15'16	3.1	1.7
June 1-2'16	95.7	14

[3] extrapolated from Figure 2.

Results

Mean values for the different variable were plotted as histograms and analyzed statistically using General Linear Interactive Models (Appendix 1). Comparisons of the different measurement variables obtained in the different rivers (aggregating across sampling sites) are shown in Figures 4a and 4b.

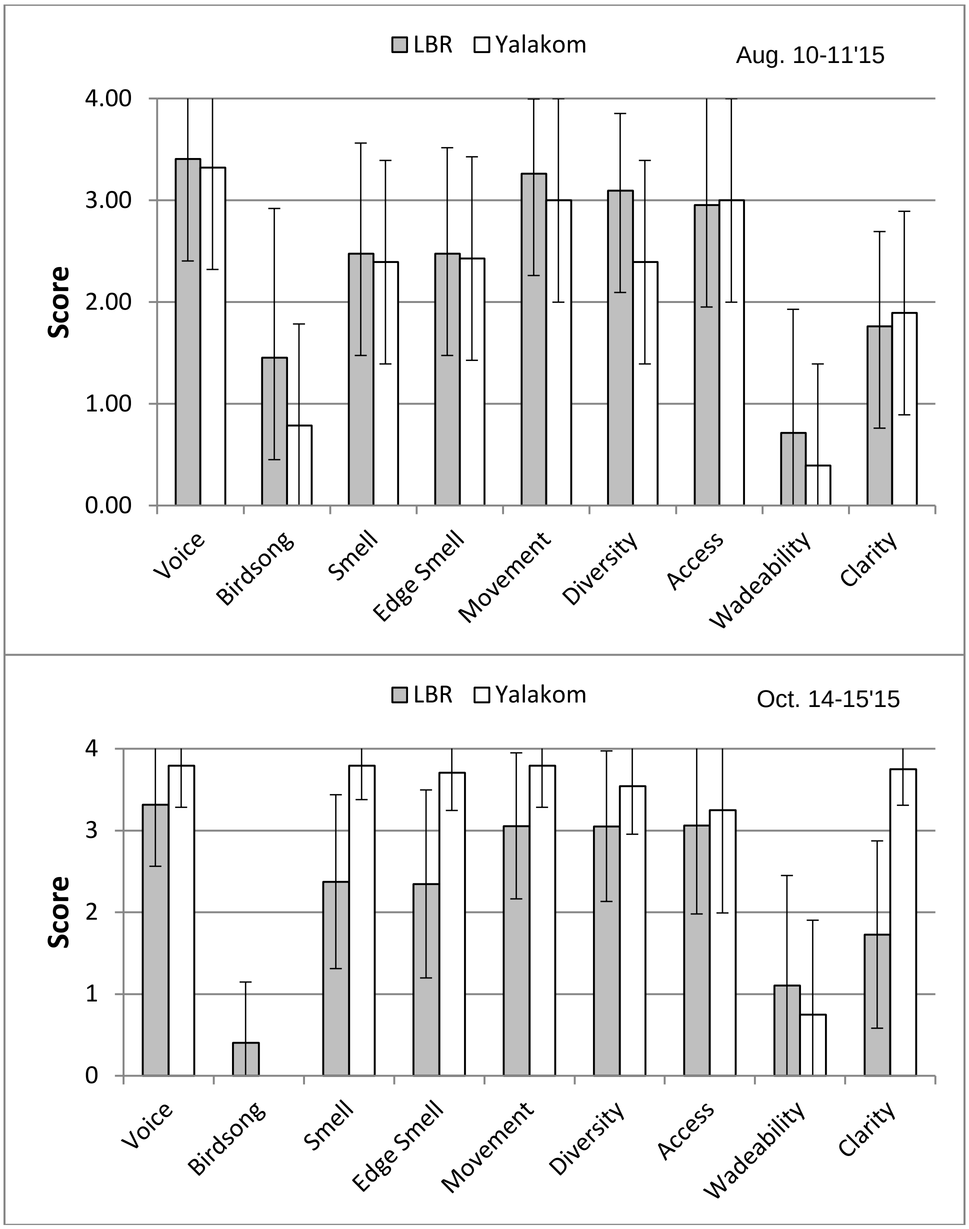

Figure 4a. Spiritual and cultural value scores in the Lower Bridge River and Yalakom River for Aug. 10-11, 2015 (upper; n = 7) and Oct. 14-15, 2015 (lower; n = 8). Error bars indicate ±1 standard deviation. Scores represent 0 = low quality, 1 = moderately low quality, 2 = moderate quality, 3 = moderately high quality and 4 = high quality.

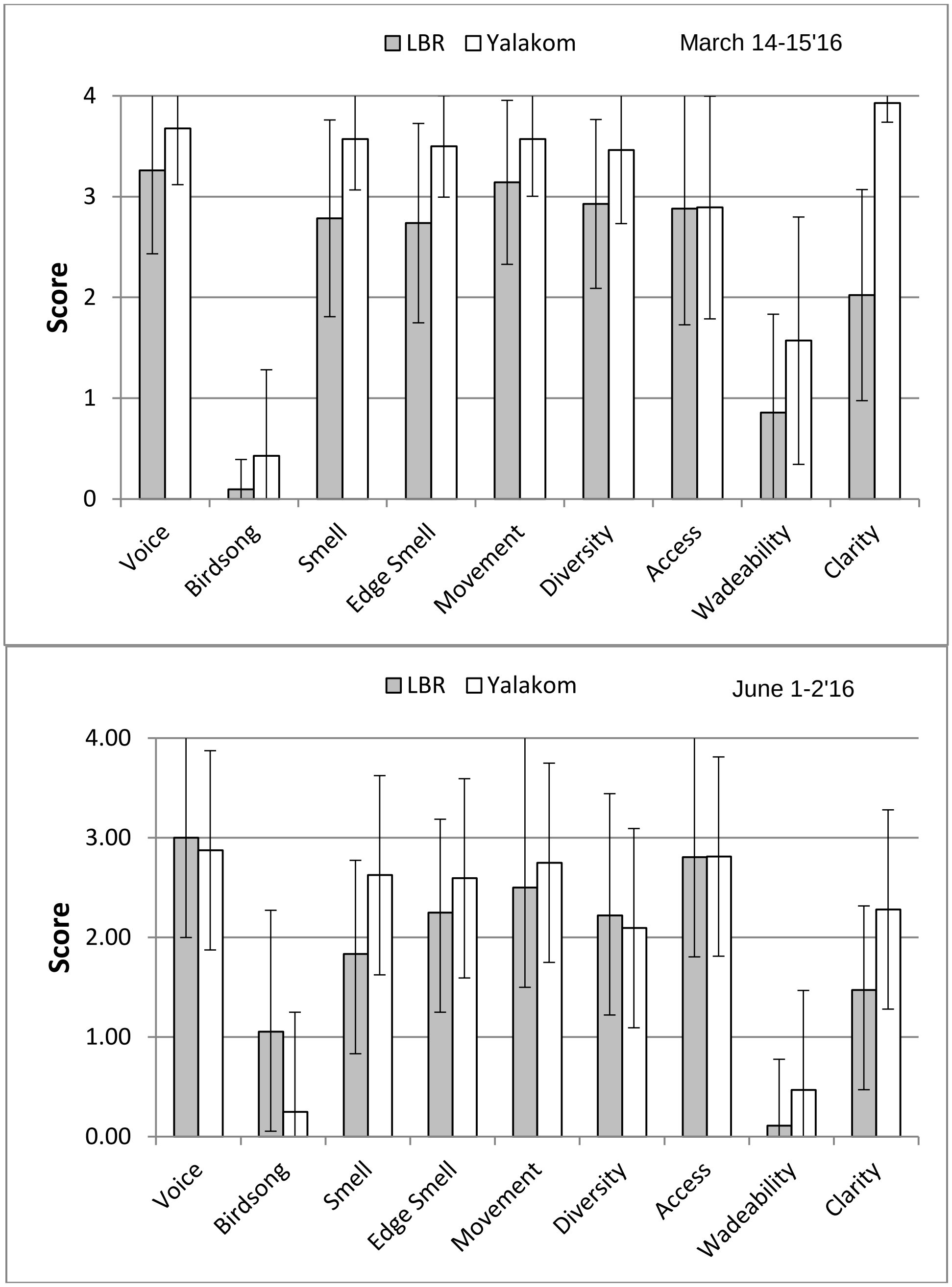

Figure 4b. Spiritual and cultural value scores in the Lower Bridge River and Yalakom River for March 14-15, 2016 (upper; n =7) and June 1-2, 2016 (lower; n = 6). Error bars indicate ±1 standard deviation. Scores represent: 0 = low quality, 1 = moderately low quality, 2 = moderate quality, 3 = moderately high quality and 4 = high quality.

To obtain a qualitative evaluation of between-elder variability in scoring trends, the nine different parameters were pooled and compared visually (Figures 5a and 5b).

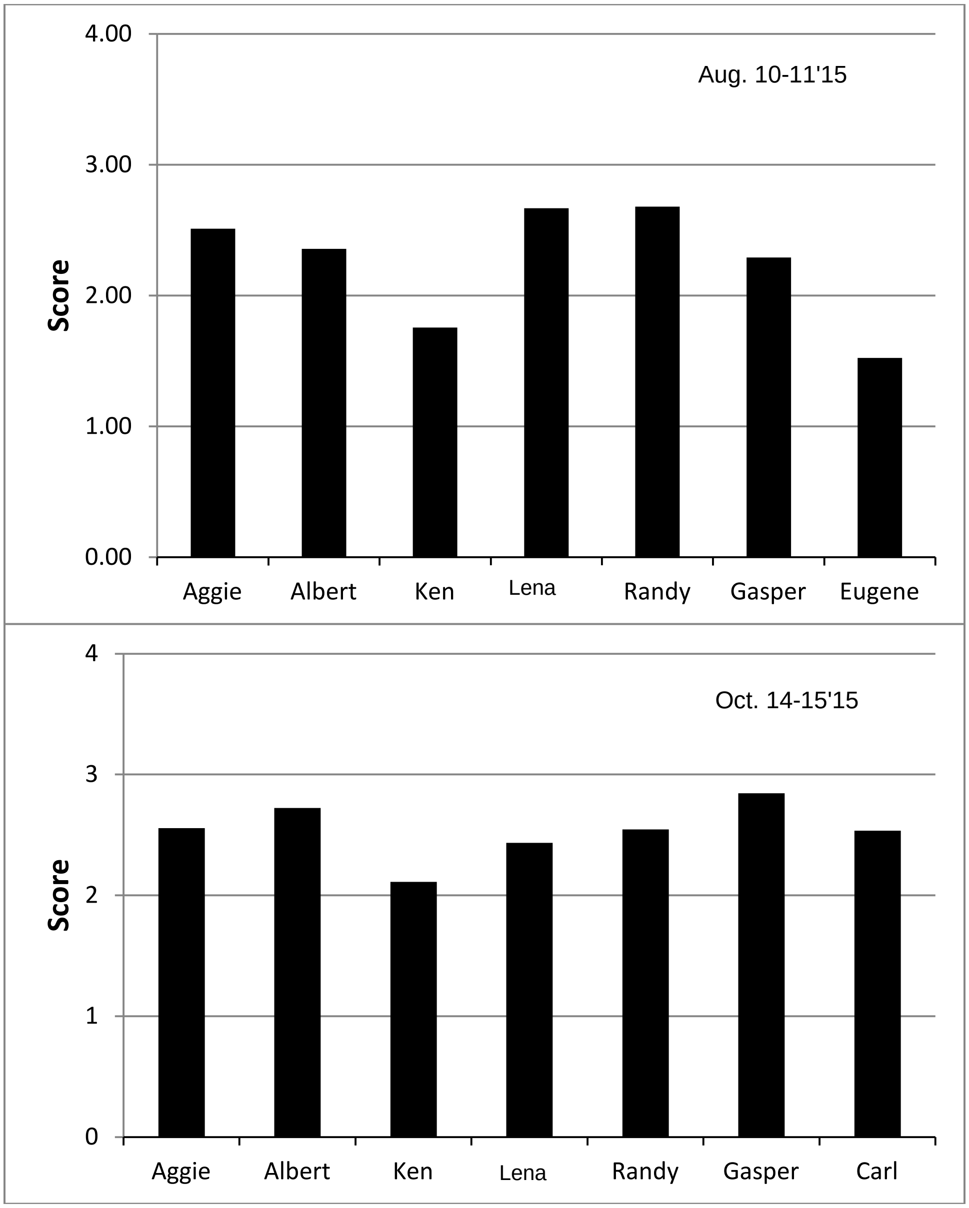

Figure 5a. Combined scores of cultural and spiritual value attributes obtained during Aug. 10-11'15 (upper) and Oct. 14-15'15 (lower).

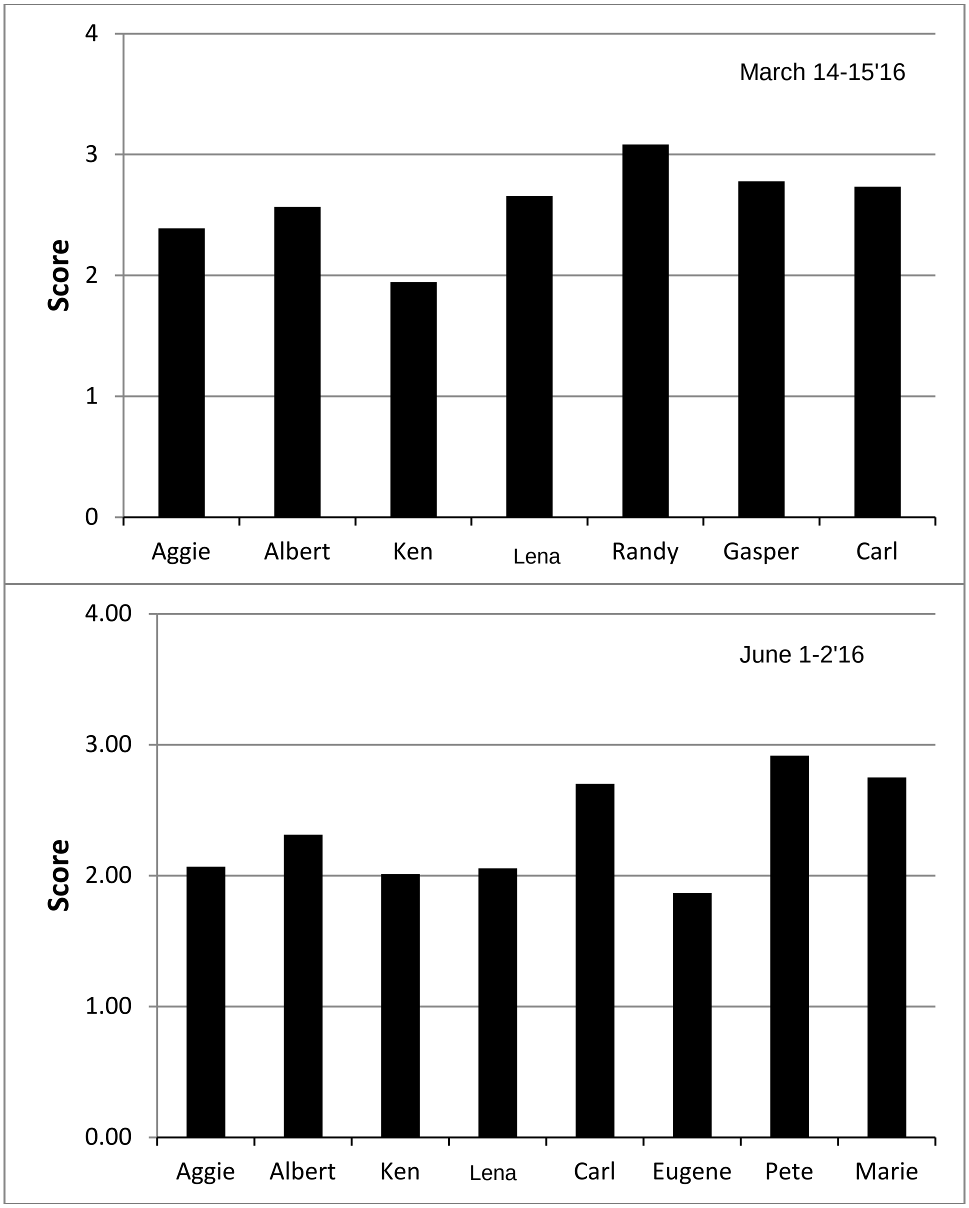

Figure 5b. Combined scores of cultural and spiritual value attributes obtained during March 14-15'16 (upper) and June 1-2'16 (lower).

To evaluate the effects of flow discharge on spiritual and cultural values, the compiled data points obtained in the Lower Bridge River during the 3 years of BRGMON-16 monitoring were plotted against discharge and is shown in Figures 6 and 7.

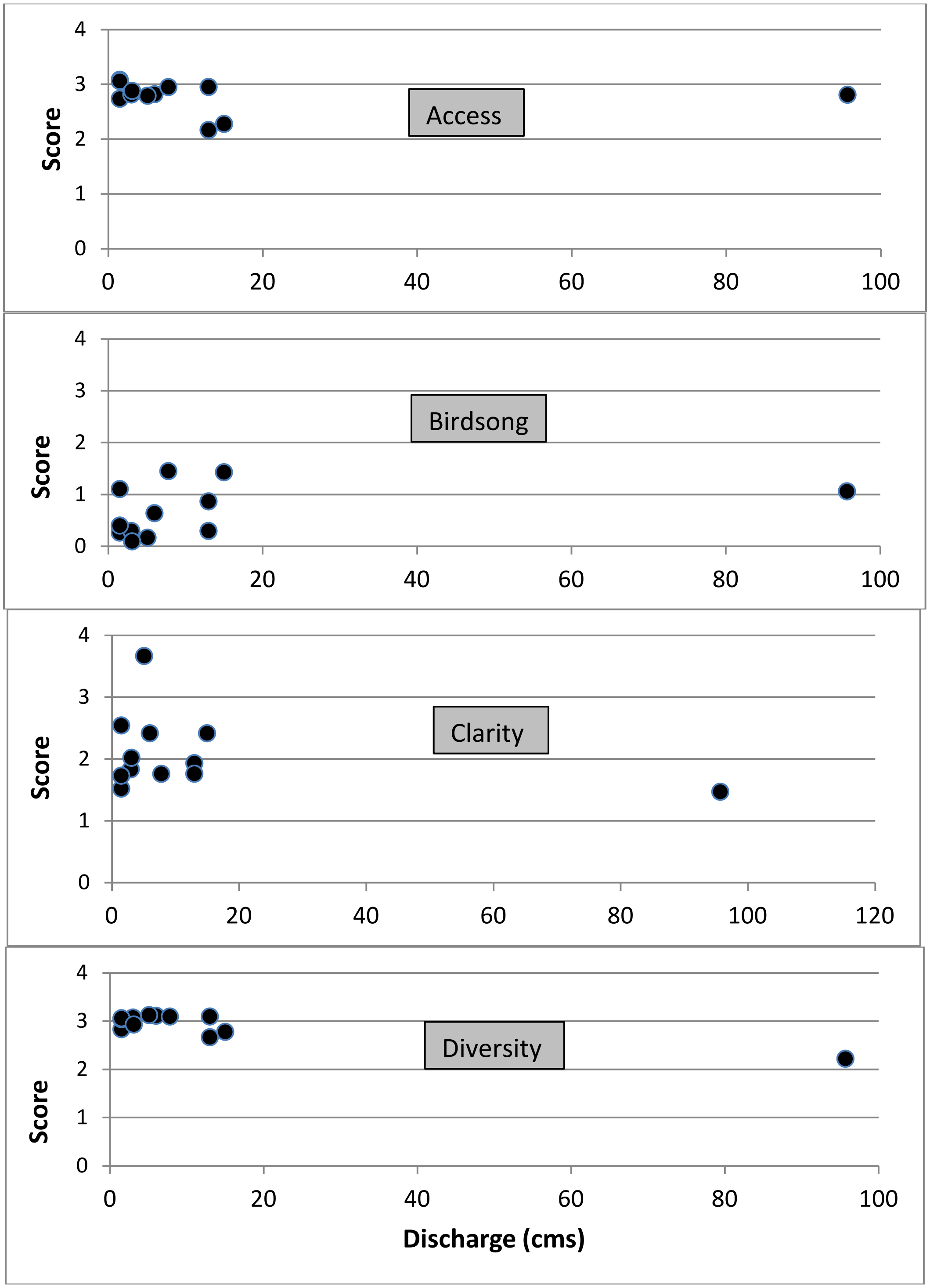

Figure 6. Scatter plots of mean scores for Access, Birdsong, Clarity and Diversity in relation to Lower Bridge River flow discharge between 2013 - 2016.

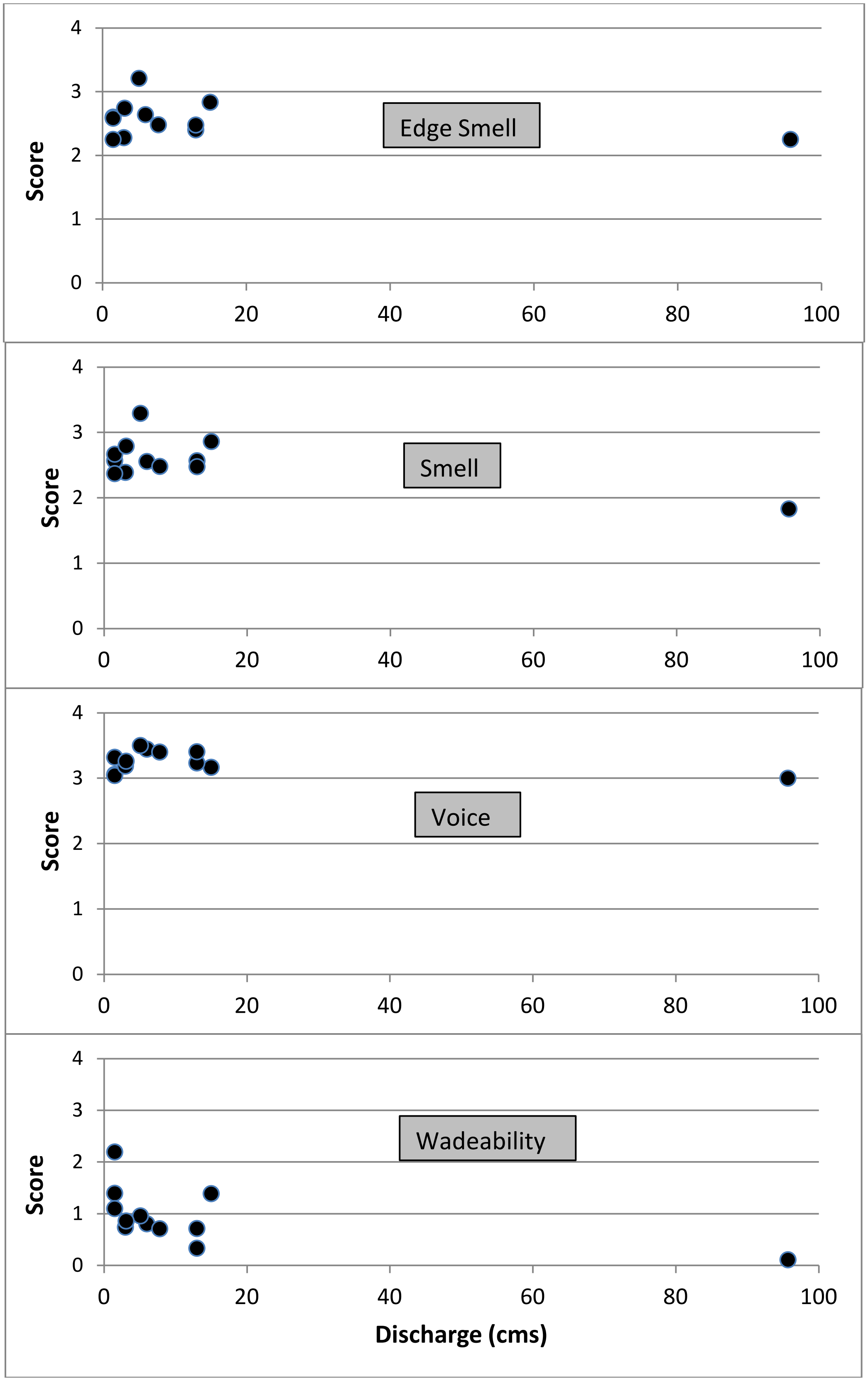

Figure 7. Mean scores for Edge Smell, Smell, Voice and Wadeability in relation to Lower Bridge River flow discharge between 2013 - 2016.

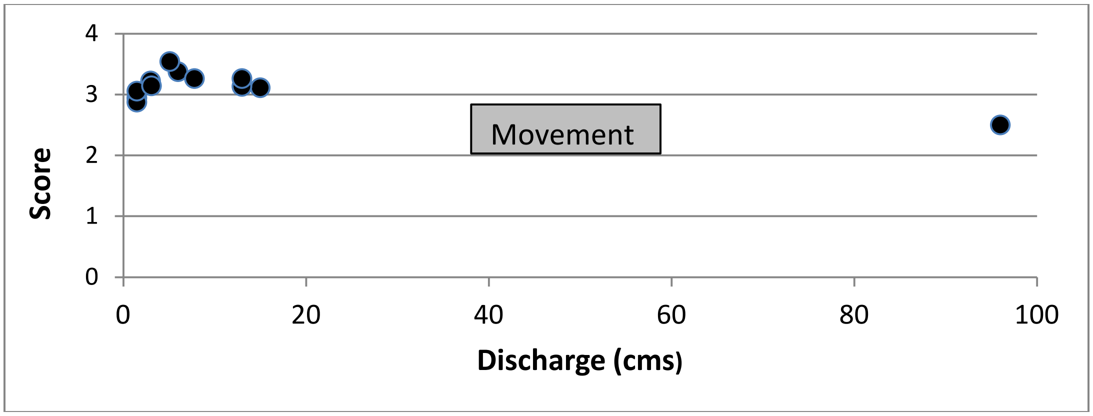

Figure 8. Mean scores for Movement in relation to Lower Bridge River flow discharge between 2013 - 2016.

Statistical Analysis Results

Statistical analysis (GLIM) of BRGMON-16 data was undertaken by Dr. Eduardo Martins[4] from the University of BC. The analysis investigated whether the scores varied between Rivers and among Seasons, while accounting for the random effects of Elder, Site and Year on the Intercept (i.e. mean score). During previous analyses (the 2014 and 2015 BRGMON-16 Annual Reports, "Year" was treated as a fixed effect since there were only 1 or 2 years of observations. For the 2016 analysis there were 3 years of observations available, justifying the consideration of "Year" as a random effect.

The steps for the analysis were:

1. Fit a model with an interaction between River and Season.
2. Assess model residuals visually (not shown but cod es for plots are available in separate txt files).
3. Run marginal tests for testing the significance of the interaction.
   - If the interaction was significant at alpha = 0.05, the full model was used for inference.
   - If the interaction was not significant at alpha = 0.05, the interaction was removed and the model was re-fitted with main effects only.
   - Conduct multiple comparison tests (Tukey's test) if the Interaction or effect of Season was found to be significant at alpha = 0.05.

During the analysis, the response variable (score 0-4) was treated as "continuous" and bounded between 0-4, making it relatively straightforward to fit a mixed model with a normal error distribution. Appendix 1 provides the statistical outputs. Main results are described below and summarized in Table 3. Note: S1 = summer; S2 = fall; S3 = winter; S4 = spring. A significant result reflects an F-value that was statistically different from zero (at alpha = 0.01).

[4] presently working for BC Hydro

Table 3. Summary of statistical results (✸ indicates significant at alpha = 0.01; ns = not significant). F-values are indicated by the numbers below the significance designations.

Parameter	Season	River	Season x River	Interpretation
Access	ns 0.12	ns 0.31	ns 0.27	There was no influence of season or river on Access scores, and no interaction between season and river.
Birdsong	✸ 22.31	✸ 4.59	✸ 7.72	There were seasonal effects on Birdsong scores, differences between rivers and an interaction between seasons and rivers. In the Bridge River: • Scores in spring were greater than in summer, fall, and winter • Scores in winter were smaller than in summer and fall In the Yalakom River: • Scores in spring were greater than in fall
Clarity	✸ 29.32	✸ 14.83	✸ 52.88	There were seasonal effects on Clarity, differences between rivers and an interaction between season and river. In the Bridge River: • Scores in summer were greater than in fall, winter, and spring • In the Yalakom River scores in spring were smaller than in summer , fall and winter Multiple comparisons between rivers within a season showed the following significant differences: • Summer, fall and winter scores in the Yalakom River were greater than in the Bridge River • Spring scores were not significantly different between rivers
Diversity	✸ 9.71	ns 2.49	ns 0.16	There were seasonal effects on Diversity but no difference between rivers and no interaction between season and river. Multiple comparisons between seasons showed that scores in spring were smaller than in summer, fall and winter
Edge Smell	✸ 3.65	✸ 9.02	✸ 7.99	There were significant differences between seasons and rivers and an interaction between season and river. Multiple comparisons between seasons within a river showed the following significant differences: • In the Bridge River there were no significant differences • In the Yalakom River, scores in spring were smaller than in summer, fall and winter Multiple comparisons between rivers within a season showed the following significant differences: • Summer scores in the Yalakom River were greater than in the Bridge River • Fall scores in the Yalakom River were greater than in the Bridge River • Winter scores in the Yalakom River were greater than in the Bridge River • Spring scores were not significantly different between rivers

Parameter	Season	River	Season x River	Interpretation
Movement	✹ 3.50	ns 2.49	✹ 3.00	There were seasonal effects on Movement, no differences between rivers and an interaction between season and river. Multiple comparisons between seasons within a river showed the following significant differences: • In the Bridge River, scores in winter were greater than the fall • In the Yalakom River there were no significant differences Multiple comparisons between rivers within seasons showed the following significant differences: • Summer scores indicated no significant difference between rivers • Fall scores in the Yalakom River were greater than in the Bridge River • Winter scores were not significantly different between Rivers • Spring scores were not significantly different between Rivers
Smell	✹ 4.68	✹ 5.24	✹ 6.78	There were significant differences between seasons and rivers and an interaction between season and river. Multiple comparisons between seasons within a river showed the following significant differences: • In the Bridge River scores in spring were smaller than in summer • In the Yalakom River scores in spring were smaller than in summer, fall and winter Multiple comparisons between rivers within a season showed the following significant differences: • Summer scores indicated no significant difference between rivers • Fall scores in the Yalakom River were greater than in the Bridge River • Winter scores in the Yalakom River were greater than in the Bridge River • Spring scores were not significantly different between Rivers
Voice	ns 1.23	✹ 3.38	ns 1.06	There were differences between rivers, no seasonal differences and no interaction between season and river. Yalakom River scores were significantly larger than Bridge River scores.
Wadeability	✹ 21.58	ns 0.17	✹ 12.26	There were seasonal differences in wadeability, no differences between rivers and an interaction between season and river. Multiple comparisons between seasons within a river showed the following significant differences: • In the Bridge River scores in spring were smaller than summer, fall, and winter. Scores in fall were greater than in summer and winter • In the Yalakom River scores in spring were smaller than summer, fall and winter. Scores in winter were larger than summer and fall Multiple comparisons between rivers within a season showed the following significant differences: • Summer scores indicated no significant difference between rivers • Fall scores indicated no significant difference between rivers • Winter scores in the Yalakom River were greater than in the Bridge River • Spring scores were not significantly different between Rivers

Discussion

The main objective of the BRGMON-16 monitoring program is to evaluate whether there are differences in the spiritual and cultural values associated with different flow discharges in two different river systems: the LBR and the Yalakom. During Year 3 of the project, the program replicated the approach of assessing cultural and spiritual attributes associated with different water flow discharges. St’át’imc elders participated as evaluators of nine different parameters related to spiritual and cultural attributes. The motivation for the project is to incorporate St’át’imc spiritual and cultural attribute considerations into a long-term flow release strategy for the LBR. The project was designed to inform the selection of either 3 cms or 6 cms mean annual flow discharges.

During 2016, there was a water spill in the LBR (maximum discharge of 96 cms) associated with the lowering of Downton Reservoir maximum elevation to 734 masl as well as reduced capacity in the system for passing flows into Seton Lake via the Bridge 1 and Bridge 2 Generating Stations due to their de-rated generator units. Similar spills are anticipated to occur in future and may be compounded during high inflow years.

Main results obtained in 2015-2016 are discussed below.

Histogram Plots

The following trends were evident in the histograms shown on Figures 4-5:

1. During the summer survey (August 10 - 11) there were minor differences in seven of the parameters and only Birdsong and Diversity were slightly higher in the LBR than in the Yalakom. The standard deviation error bars during this survey, as well as in subsequent surveys, indicate that the measured differences were small in relation to the variation in the data. During the fall (Oct. 14-15), seven parameters scored modestly higher in the Yalakom, with the exception of Birdsong and Wadeability which were slightly higher in the LBR. As in the summer survey, the error bars calculated for the 2 rivers overlapped to a large extent, e.g. Voice, Diversity, Access and Wadeability. The winter survey (March 14-15) indicated that eight parameters scored higher in the Yalakom (Voice, Smell, Edge Smell, Movement, Diversity, Wadeability and Clarity). Birdsong and Wadeability scores were similar in the 2 rivers. During the spring survey (June 1-2) most of the scores were similar in the 2 rivers, with the exception of Birdsong which was higher in the LBR and Clarity which was higher in the Yalakom.

   While the confidence in these observations is modest due to the relatively large variation in the scores (large and overlapping error bars) there is a systematic trend in the observations, such that the Yalakom scores appeared to be modestly higher than those in the LBR. Similar trends were observed in Years 1 and 2, and now that 3 years of data are available, there is a good basis for testing these observations statistically (see Summary of Statistical Results, below).

2. There was no consistent trend in the between-elder scores with the exception of Eugene and Ken who scored lower than the other elders during the surveys in which they participated.

Discharge Analysis

The scatter plots in Figures 6 and 7 did not suggest that there was a relationship between discharge and six parameters: Access, Bird Song, Clarity, Edge Smell, Voice and Wadeability (p.26). The relationships between discharge and two of the parameters, Diversity and Smell, appeared to be inversely correlated, i.e. higher discharge resulted in slightly lower scores. This reflects that elder perceptions of Diversity (pool:riffle ratio) decreased as a function of flow and likewise Smell scores also decreased.

Care must be exercised when interpreting the discharge analysis results in Figures 6 and 7 due to the high June discharge value of 96 cms which "levered" the data set, possibly leading to false conclusions about the presence/absence of an effect. For example, if there was a parabolic relationship between discharge and the parameter scores, it wouldn't be detectable due to the absence of discharge observations between 15 cms and 96 cms. In the absence of such data the simplest and most parsimonious explanation for the trend is a linear relationship.

During 2014-2015 (Year 2), a similar scatter plot as those shown in Figures 6 and 7 was generated for Voice but the data set didn't include a high value of 96 cms for the spring sample. In 2015, the previous spring sample (May 14'15) discharge was 13 cms. The results of the Voice vs. discharge comparison in Year 2 yielded a non-significant result, consistent with the Year 3 results. The consistency between years suggests that the levering effect may have been minimal.

Summary of Statistical Results

The main results from the statistical analysis are shown in Table 3. The results of the histogram analysis and the statistical analysis were largely consistent with each other which is to be expected since the underlying data are the same.

<u>Access:</u>

Statistical comparisons indicated no effects of Season, River and the Season x River interaction on Access. This result occurred while there were large difference between LBR and Yalakom flow conditions in June 2016. The histogram analysis (Figures 4a and 4b) yielded similar results so the outcome is unlikely to be an artifact, rather, it reflects a real perception by the elders that Access is insensitive to flow.

Birdsong:

There was an effect of season, river and season x river interaction on Birdsong. The seasonal effect was a strong one as indicated by the high F-value (22.31) with highest scores observed in August. This result relates to the relatively high abundance of songbirds in the LBR and the Yalakom during mid-summer. The interaction term was also significant and reflects that Yalakom Birdsong scores were higher than LBR scores during March as opposed to August, October and June when they were lower.

Clarity:

There were significant differences between seasons, rivers as well as a strongly significant season x river interaction (F=52.88). Histograms indicated similar water clarity in August, higher water clarity in the Yalakom in October and March, and marginally higher water clarity in the Yalakom in June. Observed differences in water clarity are shown in the photos below:

	Lower Bridge River (B6)	Yalakom River (Y4)
Aug. 10-11'15		
Oct. 14-15'15		
Mar. 14-15'16		
June 1-2'16		

<u>Diversity:</u>

The statistical analysis results indicated seasonal effects on Diversity but no difference between rivers and no interaction between season and river. The seasonal effect was reflected in the histograms which indicated lowest diversity in June, both in the LBR and the Yalakom.

<u>Edge Smell and Smell:</u>

Edge Smell and Smell showed similar results with significant effects of season, river and the interaction between season and river. Higher scores were obtained in the Yalakom River than the LBR in October, March and June whereas in August similar scores were obtained in the LBR. Lowest smell scores were collected in August and June.

Movement:

Scores varied between seasons and between rivers. This result is to be expected in view of the large flow variations between seasons (Figure 6). The interaction between rivers and seasons likely reflects differences in the flow hydrographs in the 2 rivers.

Wadeability:

This parameter varied seasonally and between rivers. There was also an interaction between seasons and rivers. Similar to Movement, these results likely reflect the differences in flow discharges in the two rivers in summer of 2016. The seasonal differences reflected the large seasonal flow variability with wadeability being higher under low flows. Lowest Wadeability in the LBR occurred on June 1and coincided with the 96 cms flow discharge.

Voice:

Voice observations did not vary by season and there were no season x river interactions. Scores varied between rivers such that Yalakom River scores were significantly larger than Bridge River scores.

An expanded Voice data set (n = 10) collected between August 2014 and October 2016 (Figure 9) confirmed the statistical results i.e. no seasonal effect on Voice scores and higher Voice scores in the Yalakom. Six of the ten observations were higher for the Yalakom and four of the ten observations indicated no difference.

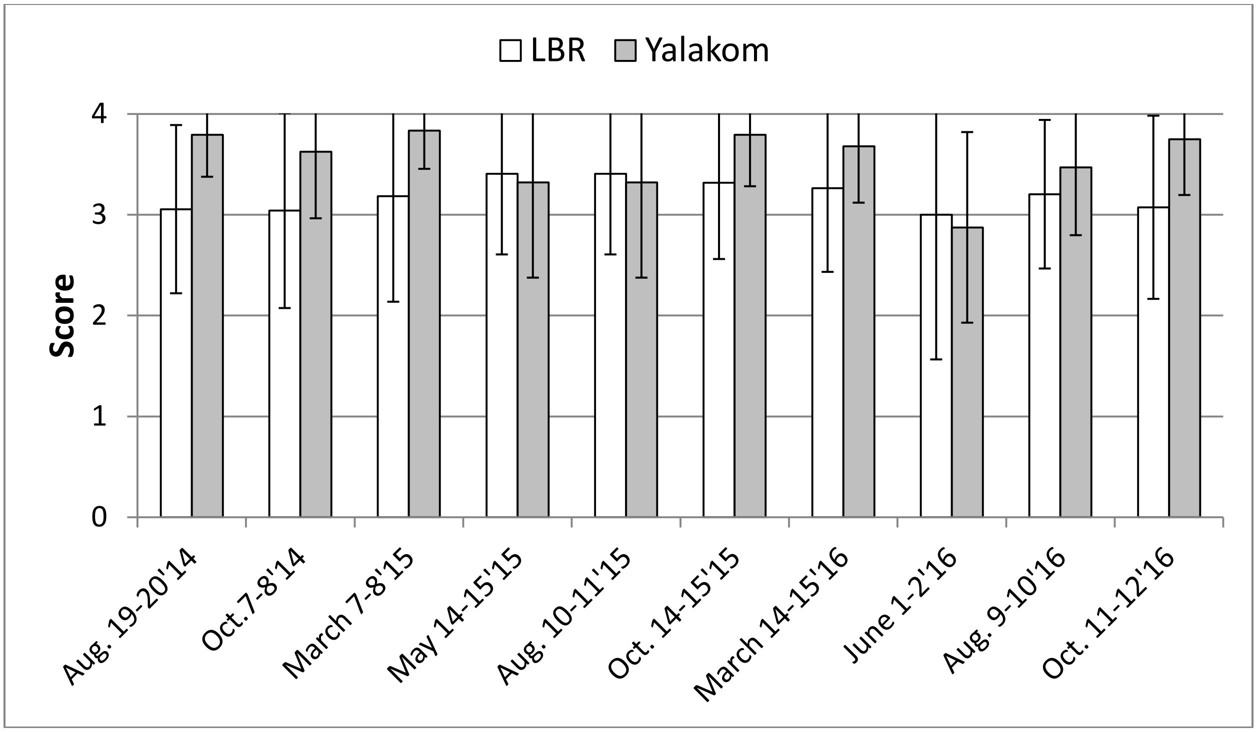

Figure 9. Mean scores for Voice in relation to Lower Bridge River flow discharge between 2014 - 2016.

During Year 3, the BRGMON-16 project replicated the quarterly monitoring that has been conducted on behalf of BC Hydro since 2013. The primary focus of the project is to understand the influence of different flow discharges on spiritual and cultural attributes, as perceived by the St'at'imc elders, of water flows in the Lower Bridge River in relation to a long term flow release strategy. As shown in Figure 3 and reflected by the photo on the Title Page, a large volume of water was spilled into the LBR during the summer of 2016 reaching a peak discharge of 96 cms. By comparison, during Years 1 and 2 of the monitoring program, the mean annual flow discharge was 6 cms and the peak was 15 cms.

Fortuitously, the June 1-2'16 survey overlapped the 96 cms flow. While a spill of 96 cms creates environmental impacts, from an experimental design perspective this outlier data point provides good contrast in the data set and serves as an opportunity to better understand trends associated with flow discharge.

Over the past 3 years BRGMON 16 data have been analyzed by:

1. time series of histogram plots for the LBR and Yalakom (Figures 4a and 4b)
2. statistical analysis via General Linear Modeling (Table 3 and Appendix 1)
3. evaluating relationships between parameter values and flow discharge (Figures 6 and 7)

The 3 approaches reinforce each other. As the data set builds over time it is possible to draw stronger conclusions and to better understand assumptions. For variables which co-vary, e.g. discharge and season, histograms indicated that counterintuitively, seasonal effects were minimal (e.g. low variation in Voice scores between seasons in Figure 8). In view of low seasonal variation and the elimination of seasonality as a confounding variable with flow discharge, it was justifiable to directly analyze variations in parameter values in relation to flow discharges (Figures 6 and 7). The latter measure provides the best measure for determining the influence of flow discharge on spiritual and cultural values. The results of the latter analysis indicated that there was no influence of flow discharge on the measured cultural and spiritual value attributes. It seems counterintuitive that the spiritual and cultural parameters were insensitive to flow but that is the justifiable conclusion from the analysis.

The existing management question which provided the framework for monitoring was:

> "How does the smell, sound, movement and interaction (of people and water) on the Lower Bridge River under the 6 cms/y flow regime compare with that in the Yalakom River, an adjacent unregulated tributary of the Lower Bridge River?"

Yalakom River values were consistently higher than LBR values when all 3 years of data were evaluated by GLIM testing. Similar trends were observed in Years 1 and 2 but the differences were small and the sample size wasn't sensitive enough to render a significant result in those years. The Year 3 result will be further tested in Years 4 and 5 and it is expected that the additional monitoring data will further strengthen this conclusion.

In light of the higher flows experienced in 2016, the data collected during these years will not accurately describe a 6 cms Mean Annual Discharge, but instead will provide an opportunity to explore how sensitive the Spiritual and Cultural scores are to high flows that better approximate historical discharges along the LBR. As shown in this report, the Spritual and Cultural scores appear to be insensitive to extreme peak flows that can be up to eight times higher than those which occurred in the 2013-2014 years.

While the higher spiritual and cultural value results in the Yalakom are informative, they provide only modest insight for flow management planning in the LBR. A sensitivity analysis of the spiritual and cultural scores will generate a useful framework for directly determining the effects of flow discharge on spiritual and cultural values. Further testing in Year 5 will provide a direct monitoring measure to inform flow management practices in the LBR. If future monitoring data support the Year 3 and 4 conclusion that spiritual and cultural parameters are largely insensitive to discharge, this will provide useful information for Structured Decision Making designed to determine a long-term flow release strategy for the LBR.

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Appendix 1. Statistical Analysis Results

Access

This analysis investigates whether the scores varied between rivers (River) and among seasons (Time), while accounting for the random effects of Elder, Site and Year on the Intercept (i.e. mean score). The steps for the analysis were:

1. Fit a model with an interaction between River and Time.
2. Assess model residuals visually (not shown but codes for plots available in the txt file).
3. Run marginal tests for testing the significance of the interaction.
   - If the interaction was significant at $\alpha = 0.05$, the full model was used for inference.
   - If the interaction was not significant at $\alpha = 0.05$, the interaction was removed and the model was re-fitted with main effects only.
4. Conduct multiple comparison tests (Tukey's test) if the Interaction or effect of Season were found to be significant at $\alpha = 0.05$.

Marginal tests of significance applied to the full model for **Access** revealed that the interaction term was not significant (Table 1). The same test was run on the model re-fitted with main effects only, but the results revealed that neither River nor Season were associated with the scores (Table 2). Estimates for individual fixed effects are presented in Table 3.

Table 1: Marginal tests of significance for full model of **Access**.

	numDF	denDF	F-value	p-value
(Intercept)	1	803	103.67	0.00
Time	3	803	1.34	0.26
River	1	803	2.76	0.10
Time:River	3	803	1.32	0.27

Table 2: Marginal tests of significance for model of **Access** containing only the main effects.

	numDF	denDF	F-value	p-value
(Intercept)	1	806	114.24	0.00
Time	3	806	1.54	0.20
River	1	806	1.02	0.31

Table 3: Estimates of main effects in the model for **Access** with associated standard error (SE), degrees of freedom (DF), t-test statistic and p-value.

	Value	SE	DF	t-value	p-value
(Intercept)	2.8218	0.2920	806	9.6651	0.0000
TimeT2	0.0966	0.0940	806	1.0270	0.3047
TimeT3	-0.0628	0.0941	806	-0.6679	0.5044
TimeT4	-0.0911	0.0960	806	-0.9491	0.3429
RiverYalakom	0.2935	0.3134	806	0.9362	0.3494

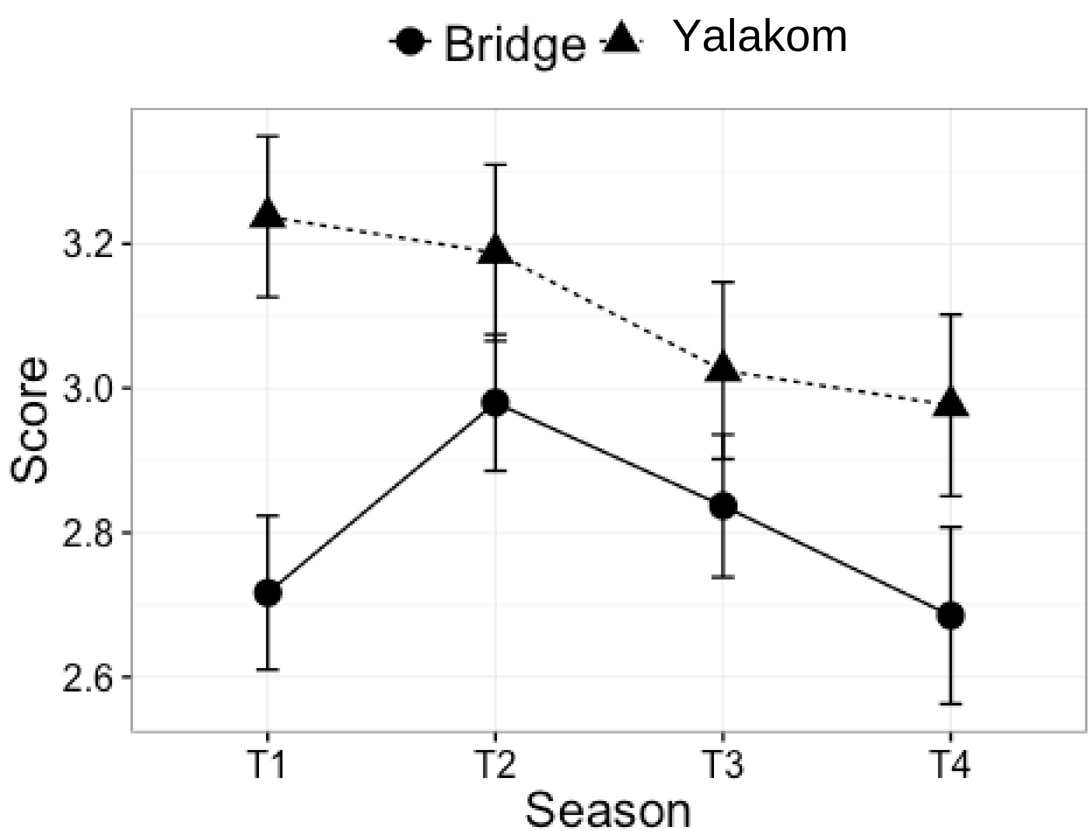


Figure 1: Interaction plot showing mean scores (± 1SE) for **Access** by river and season.

There was as much variation in scores among Elders as among Sites (see SD in TABLE 4). Variation in scores among years was low, being about less than half of the variation among Elders or Sites (Table 4).

Table 4: Standard deviation (SD) estimates for the random effects of Elder, Site and Year in the model for **Access**.

Random Effect	SD
Elder	0.4620
Site	0.4741
Year	0.1877
Residual	0.9414

An estimate of how much the Intercept (equivalent to mean score) changed by Elder, Site and Year is provided in Tables 5, 6, and 7, respectively. Positive and negative values mean the scores given are consistently above or below average (i.e. Intercept), respectively.

Table 5: Deviation from Intercept by **Elder**.

	(Intercept)
Aggie	0.0643
Albert	-0.6665
Carl	0.1951
Eugene	-0.6249
Gasper	0.7910
Ken	0.3762
Lena	0.0927
Marie	0.1153
Pete	-0.0795
Randy	-0.2636

Table 6: Deviation from Intercept by **Site**.

	(Intercept)
B1	0.6279
B2	-0.2197
B3	0.5043
B4	-0.3316
B5	-0.3021
B6	-0.2787
Y1	0.0566
Y2	0.5371
Y3	0.0712
Y4	-0.6649

Table 7: Deviation from Intercept by **Year**.

	(Intercept)
2013_14	-0.2046
2014_15	0.1272
2015_16	0.0774

Bird Song

This analysis investigates whether the scores varied between rivers (River) and among seasons (Time), while accounting for the random effects of Elder, Site and Year on the Intercept (i.e. mean score). The steps for the analysis were:

1. Fit a model with an interaction between River and Time.
2. Assess model residuals visually (not shown but codes for plots available in the txt file).
3. Run marginal tests for testing the significance of the interaction.
   - If the interaction was significant at $\alpha = 0.05$, the full model was used for inference.
   - If the interaction was not significant at $\alpha = 0.05$, the interaction was removed and the model was re-fitted with main effects only.
4. Conduct multiple comparison tests (Tukey's test) if the Interaction or effect of Season were found to be significant at $\alpha = 0.05$.

Marginal tests of significance applied to the full model for **Bird Song** revealed that the interaction term (Time x River) was significant (Table 1). Therefore, the full model was retained for inference. Estimates for individual fixed effects are presented in Table 2.

Table 1: Marginal tests of significance for full model of **Bird Song**.

	numDF	denDF	F-value	p-value
(Intercept)	1	802	17.95	0.00
Time	3	802	22.31	0.00
River	1	802	4.59	0.03
Time:River	3	802	7.72	0.00

Table 2: Estimates of fixed effects in the model for **Bird Song** with associated standard error (SE), degrees of freedom (DF), t-test statistic and p-value.

	Value	SE	DF	t-value	p-value
(Intercept)	0.9273	0.2434	802	3.8096	0.0001
TimeT2	-0.1862	0.1137	802	-1.6373	0.1020
TimeT3	-0.5595	0.1127	802	-4.9639	0.0000
TimeT4	0.3692	0.1182	802	3.1231	0.0019
RiverYalakom	-0.5219	0.2579	802	-2.0237	0.0433
TimeT2:RiverYalakom	0.0436	0.1802	802	0.2416	0.8091
TimeT3:RiverYalakom	0.7005	0.1791	802	3.9116	0.0001
TimeT4:RiverYalakom	-0.0334	0.1824	802	-0.1830	0.8548

Multiple comparisons between Times within a river showed the following significant differences (see detailed results in Table 3 and Figure 1):

- Bridge River
  - Scores in T4 were **greater** than in T1, T2, and T3
  - Scores in T3 were **smaller** than in T1 and T2
- Yalakom River
  - Scores in T4 were **greater** than in T2

Table 3: Multiple comparisons of scores between seasons within a river. H0 denotes the null hypothesis being tested (i.e. difference equal to 0).

Contrast	H0	Estimate	SE	Test Statistic	P
T1.Bridge - T2.Bridge	0	0.1862	0.1137	1.6373	0.5871
T1.Bridge - T3.Bridge	0	0.5595	0.1127	4.9639	0.0000
T1.Bridge - T4.Bridge	0	-0.3692	0.1182	-3.1231	0.0192
T2.Bridge - T3.Bridge	0	0.3734	0.1110	3.3640	0.0085
T2.Bridge - T4.Bridge	0	-0.5554	0.1168	-4.7543	0.0000
T3.Bridge - T4.Bridge	0	-0.9287	0.1158	-8.0198	0.0000
T1.Yalakom - T2.Yalakom	0	0.1426	0.1404	1.0157	0.9325
T1.Yalakom - T3.Yalakom	0	-0.1410	0.1408	-1.0019	0.9366
T1.Yalakom - T4.Yalakom	0	-0.3358	0.1396	-2.4060	0.1461
T2.Yalakom - T3.Yalakom	0	-0.2836	0.1404	-2.0207	0.3280
T2.Yalakom - T4.Yalakom	0	-0.4784	0.1397	-3.4258	0.0069
T3.Yalakom - T4.Yalakom	0	-0.1948	0.1381	-1.4110	0.7422

Multiple comparisons between rivers within a season showed no significant differences (see detailed results in Table 4 and Figure 1):

Table 4: Multiple comparisons of scores between rivers within a season. H0 denotes the null hypothesis being tested (i.e. difference equal to 0).

Contrast	H0	Estimate	SE	Test Statistic	P
T1.Yalakom - T1.Bridge	0	-0.5219	0.2579	-2.0237	0.1064
T2.Yalakom - T2.Bridge	0	-0.4784	0.2573	-1.8590	0.1502
T3.Yalakom - T3.Bridge	0	0.1786	0.2565	0.6964	0.8160
T4.Yalakom - T4.Bridge	0	-0.5553	0.2589	-2.1452	0.0815

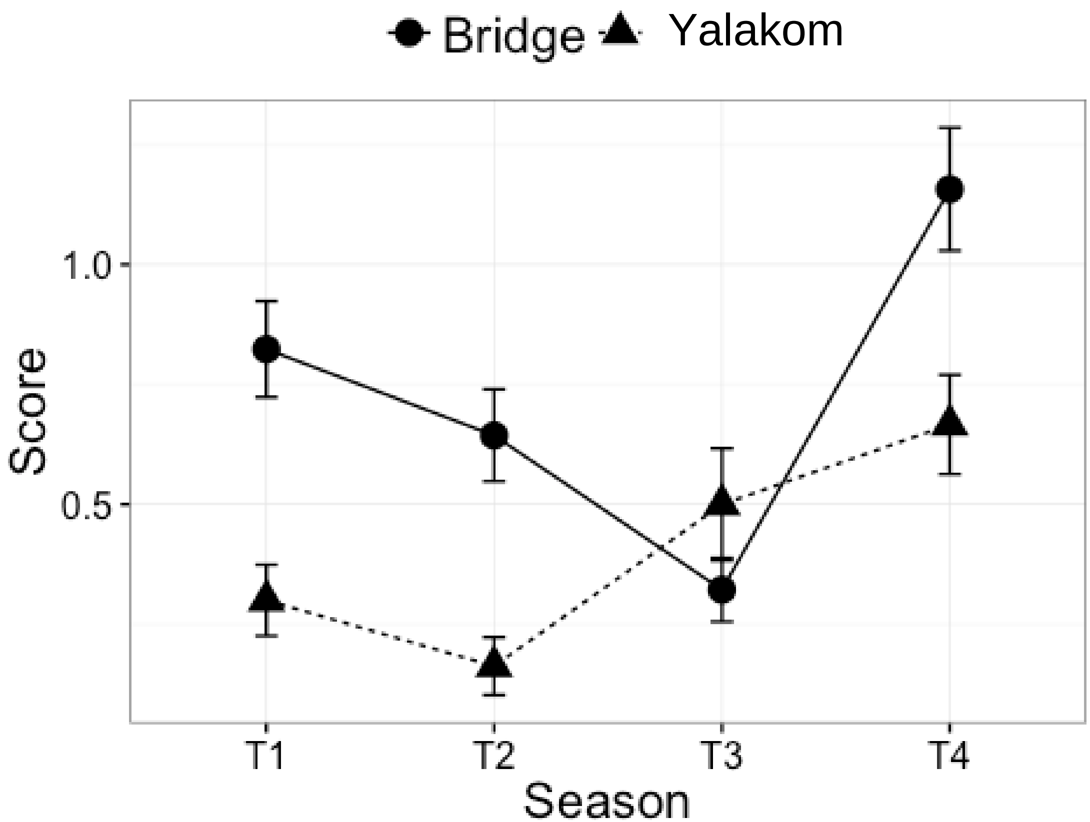


Figure 1: Interaction plot showing mean scores (± 1SE) for **Bird Song** by river and season.

There was about 1.2 times as much variation in scores among Elders than among Sites (see SD in Table 5). Variation in scores among years was low, being about one-third of the variation among Elders or Sites (Table 5).

Table 5: Standard deviation (SD) estimates for the random effects of Elder, Site and Year in the model for **Bird Song**.

Random Effect	SD
Elder	0.4290
Site	0.3468
Year	0.1334
Residual	0.8856

An estimate of how much the Intercept (equivalent to mean score) changed by Elder, Site and Year is provided in Tables 6, 7, and 8, respectively. Positive and negative values mean the scores given are consistently above or below average (i.e. Intercept), respectively.

Table 6: Deviation from Intercept by **Elder**.

	(Intercept)
Aggie	-0.2382
Albert	-0.2940
Carl	0.0335
Eugene	-0.3805
Gasper	-0.3331
Ken	0.0868
Lena	-0.1855
Marie	0.0868
Pete	0.9991
Randy	0.2251

Table 7: Deviation from Intercept by **Site**.

	(Intercept)
B1	0.7107
B2	-0.0476
B3	0.1737
B4	-0.3405
B5	-0.0777
B6	-0.4186
Y1	0.0103
Y2	-0.0705
Y3	-0.1263
Y4	0.1865

Table 8: Deviation from Intercept by **Year**.

	(Intercept)
2013_14	0.0436
2014_15	0.0953
2015_16	-0.1389

Clarity

This analysis investigates whether the scores varied between rivers (River) and among seasons (Time), while accounting for the random effects of Elder, Site and Year on the Intercept (i.e. mean score). The steps for the analysis were:

1. Fit a model with an interaction between River and Time.
2. Assess model residuals visually (not shown but codes for plots available in the txt file).
3. Run marginal tests for testing the significance of the interaction.
   - If the interaction was significant at $\alpha = 0.05$, the full model was used for inference.
   - If the interaction was not significant at $\alpha = 0.05$, the interaction was removed and the model was re-fitted with main effects only.
4. Conduct multiple comparison tests (Tukey's test) if the Interaction or effect of Season were found to be significant at $\alpha = 0.05$.

Marginal tests of significance applied to the full model for **Clarity** revealed that the interaction term was significant (Table 1). Therefore, the full model was retained for inference. Estimates for individual fixed effects are presented in Table 2.

Table 1: Marginal tests of significance for full model of **Clarity**.

	numDF	denDF	F-value	p-value
(Intercept)	1	802	172.98	0
Time	3	802	29.32	0
River	1	802	14.83	0
Time:River	3	802	52.88	0

Table 2: Estimates of fixed effects in the model for **Clarity** with associated standard error (SE), degrees of freedom (DF), t-test statistic and p-value.

	Value	SE	DF	t_value	P
(Intercept)	2.6377	0.2253	802	11.7069	0e+00
TimeT2	-0.8352	0.1100	802	-7.5909	0e+00
TimeT3	-0.6646	0.1088	802	-6.1058	0e+00
TimeT4	-0.9684	0.1142	802	-8.4801	0e+00
RiverYalakom	0.9167	0.2529	802	3.6250	3e-04
TimeT2:RiverYalakom	1.0712	0.1745	802	6.1392	0e+00
TimeT3:RiverYalakom	1.0056	0.1732	802	5.8061	0e+00
TimeT4:RiverYalakom	-0.8213	0.1764	802	-4.6552	0e+00

Multiple comparisons between seasons within a river showed the following significant differences (see detailed results in Table 3 and Figure 1):

- Bridge River
  - Scores in T1 were **greater** than in T2, T3, and T4
- Yalakom River
  - Scores in T4 were **smaller** than in T1, T2, and T3

Table 3: Multiple comparisons of scores between seasons within a river. H0 denotes the null hypothesis being tested (i.e. difference equal to 0).

Contrast	H0	Estimate	SE	Test Statistic	P
T1.Bridge - T2.Bridge	0	0.8352	0.1100	7.5909	0.0000
T1.Bridge - T3.Bridge	0	0.6646	0.1088	6.1058	0.0000
T1.Bridge - T4.Bridge	0	0.9684	0.1142	8.4801	0.0000
T2.Bridge - T3.Bridge	0	-0.1707	0.1077	-1.5855	0.6240
T2.Bridge - T4.Bridge	0	0.1331	0.1133	1.1748	0.8723
T3.Bridge - T4.Bridge	0	0.3038	0.1121	2.7104	0.0668
T1.Yalakom - T2.Yalakom	0	-0.2360	0.1359	-1.7365	0.5164
T1.Yalakom - T3.Yalakom	0	-0.3411	0.1362	-2.5043	0.1149
T1.Yalakom - T4.Yalakom	0	1.7897	0.1351	13.2494	0.0000
T2.Yalakom - T3.Yalakom	0	-0.1051	0.1358	-0.7737	0.9821
T2.Yalakom - T4.Yalakom	0	2.0257	0.1351	14.9887	0.0000
T3.Yalakom - T4.Yalakom	0	2.1308	0.1336	15.9439	0.0000

Multiple comparisons between rivers within a season showed the following significant differences (see detailed results in Table 4 and Figure 1):

- T1
  - Scores in the Yalakom River were **greater** than in the Bridge River
- T2
  - Scores in the Yalakom River were **greater** than in the Bridge River
- T3
  - Scores in the Yalakom River were **greater** than in the Bridge River
- T4
  - No signficant difference in scores between Rivers.

Table 4: Multiple comparisons of scores between rivers within a season. H0 denotes the null hypothesis being tested (i.e. difference equal to 0).

Contrast	H0	Estimate	SE	Test Statistic	P
T1.Yalakom - T1.Bridge	0	0.9167	0.2529	3.6250	0.0012
T2.Yalakom - T2.Bridge	0	1.9879	0.2525	7.8724	0.0000
T3.Yalakom - T3.Bridge	0	1.9223	0.2516	7.6395	0.0000
T4.Yalakom - T4.Bridge	0	0.0953	0.2539	0.3755	0.9713

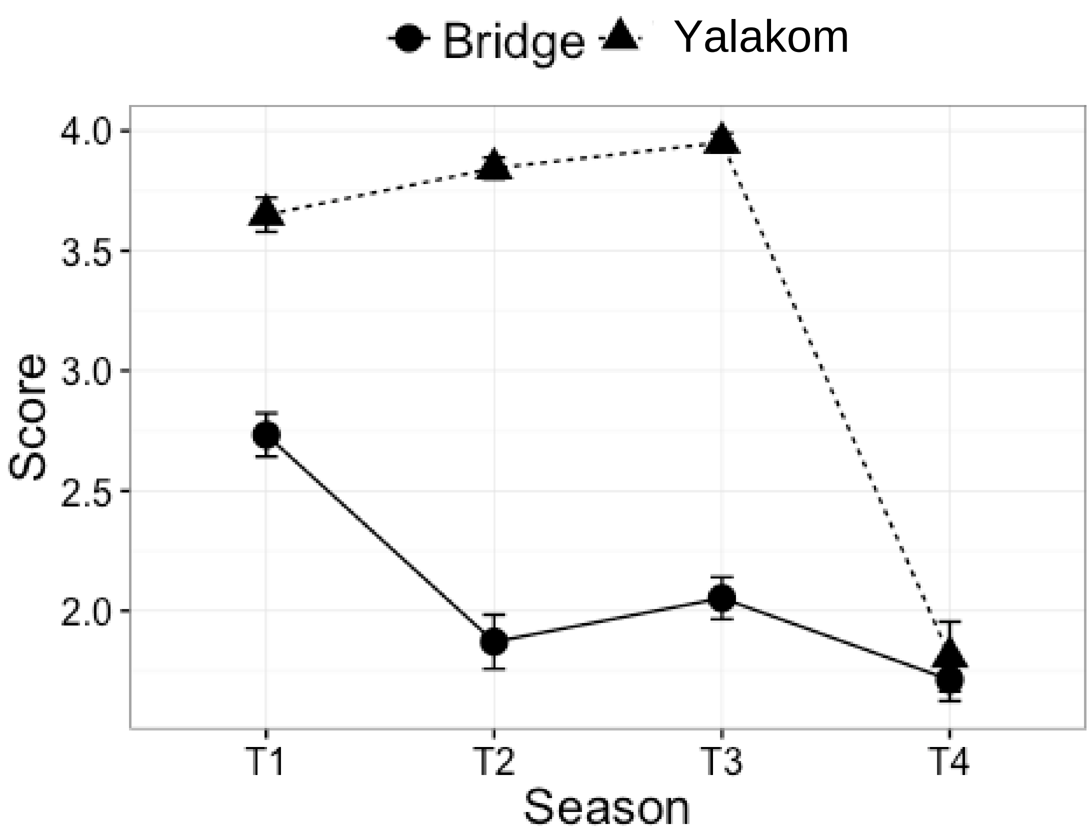


Figure 1: Interaction plot showing mean scores (± 1SE) for **Clarity** by river and season.

There was as much variation in scores among Elders as among Sites (see SD in Table 5). Variation in scores among years was low, being about one-quarter of the variation among Elders or Sites (Table 5).

Table 5: Standard deviation (SD) estimates for the random effects of Elder, Site and Year in the model for Clarity.

Random Effect	SD
Elder	0.3812
Site	0.3416
Year	0.0943
Residual	0.8574

An estimate of how much the Intercept (equivalent to mean score) changed by Elder, Site and Year is provided in Tables 6, 7, and 8, respectively. Positive and negative values mean the scores given are consistently above or below average (i.e. Intercept), respectively.

Table 6: Deviation from Intercept by **Elder**.

	(Intercept)
Aggie	0.1598
Albert	0.3573
Carl	0.3136
Eugene	-0.7199
Gasper	-0.4402
Ken	-0.0695
Lena	0.0769
Marie	-0.1873
Pete	0.3684
Randy	0.1409

Table 7: Deviation from Intercept by **Site**.

	(Intercept)
B1	-0.5708
B2	-0.2927
B3	0.0395
B4	-0.0922
B5	0.5092
B6	0.4071
Y1	0.0587
Y2	0.0681
Y3	-0.0214
Y4	-0.1054

Table 8: Deviation from Intercept by **Year**.

	(Intercept)
2013_14	-0.0909
2014_15	0.0228
2015_16	0.0681

Diversity

This analysis investigates whether the scores varied between rivers (River) and among seasons (Time), while accounting for the random effects of Elder, Site and Year on the Intercept (i.e. mean score). The steps for the analysis were:

1. Fit a model with an interaction between River and Time.
2. Assess model residuals visually (not shown but codes for plots available in the txt file).
3. Run marginal tests for testing the significance of the interaction.
    - If the interaction was significant at $\alpha = 0.05$, the full model was used for inference.
    - If the interaction was not significant at $\alpha = 0.05$, the interaction was removed and the model was re-fitted with main effects only.
4. Conduct multiple comparison tests (Tukey's test) if the Interaction or effect of Season were found to be significant at $\alpha = 0.05$.

Marginal tests of significance applied to the full model for **Diversity** revealed that the interaction term was not significant (Table 1). The same test was run on the model re-fitted with main effects only, revealing that Time was significantly associated with the scores (Table 2). Estimates for individual fixed effects are presented in Table 3.

Table 1: Marginal tests of significance for full model of **Diversity**.

	numDF	denDF	F-value	p-value
(Intercept)	1	803	323.00	0.00
Time	3	803	2.48	0.06
River	1	803	0.66	0.42
Time:River	3	803	1.71	0.16

Table 2: Marginal tests of significance for model of **Diversity** containing only the main effects.

	numDF	denDF	F-value	p-value
(Intercept)	1	806	343.52	0.00
River	1	806	2.46	0.12
Time	3	806	9.71	0.00

Table 3: Estimates of main effects in the model for **Diversity** with associated standard error (SE), degrees of freedom (DF), t-test statistic and p-value.

	Value	SE	DF	t-value	p-value
(Intercept)	2.9905	0.1850	806	16.1665	0.0000
RiverYalakom	0.1232	0.0837	806	1.4716	0.1415
TimeT2	0.0862	0.0811	806	1.0626	0.2883
TimeT3	0.0793	0.0811	806	0.9773	0.3287
TimeT4	-0.3008	0.0829	806	-3.6299	0.0003

Multiple comparisons between seasons showed the following significant differences (see detailed results in Table 4 and Figure 1):

- Scores in T4 were **smaller** than in T1, T2, and T3

Table 4: Multiple comparisons of scores between seasons. H0 denotes the null hypothesis being tested (i.e. difference equal to 0).

Contrast	H0	Estimate	SE	Test Statistic	P
T1 - T2	0	-0.0862	0.0811	-1.0626	0.7123
T1 - T3	0	-0.0793	0.0811	-0.9773	0.7624
T1 - T4	0	0.3008	0.0829	3.6299	0.0016
T2 - T3	0	0.0069	0.0802	0.0858	0.9998
T2 - T4	0	0.3869	0.0824	4.6958	0.0000
T3 - T4	0	0.3800	0.0815	4.6608	0.0000

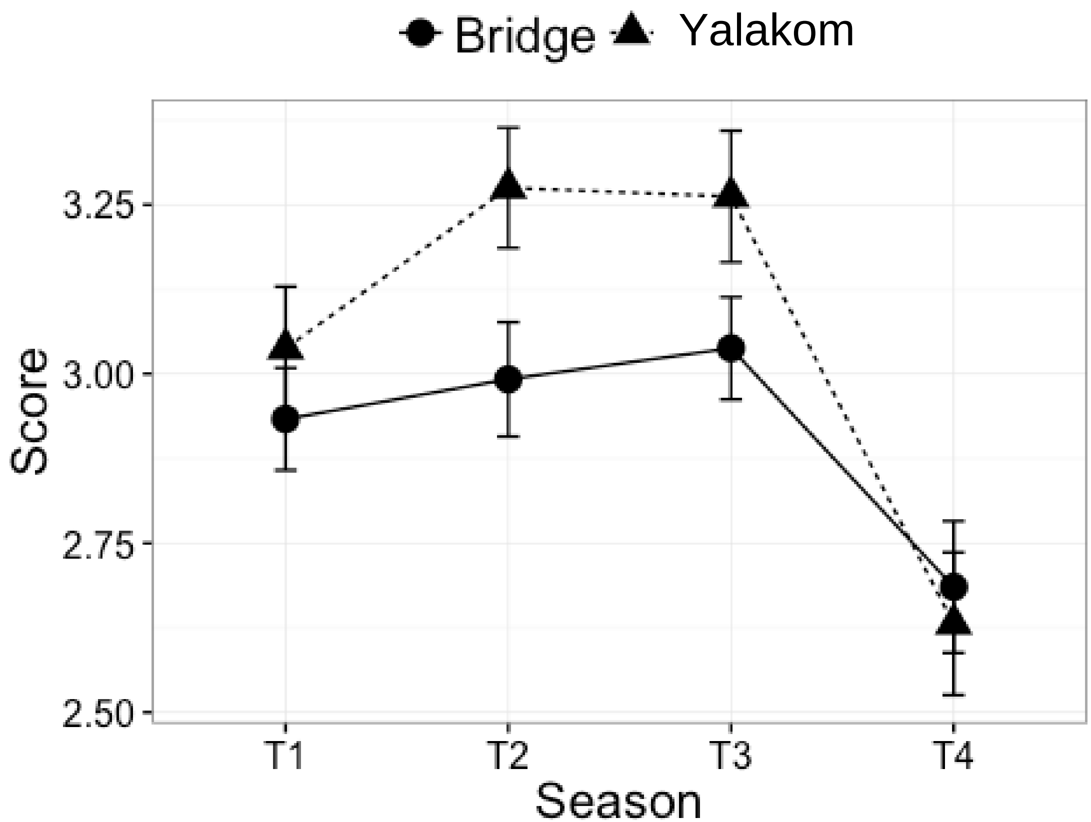


Figure 1: Interaction plot showing mean scores (± 1SE) for **Diversity** by river and season.

A much larger amount of the variability in scores for **Diversity** was associated with Elders, with about 5 and 8 times as much variation in scores among Elders than among Sites or Years, respectively. (see SD in Table 5).

Table 5: Standard deviation (SD) estimates for the random effects of Elder, Site and Year in the model for Diversity.

Random Effect	SD
Elder	0.4596
Site	0.0922
Year	0.0565
Residual	0.8115

An estimate of how much the Intercept (equivalent to mean score) changed by Elder, Site and Year is provided in Tables 6, 7, and 8, respectively. Positive and negative values mean the scores given are consistently above or below average (i.e. Intercept), respectively.

Table 6: Deviation from Intercept by **Elder**.

	(Intercept)
Aggie	-0.3529
Albert	0.2899
Carl	-0.2500
Eugene	-0.9095
Gasper	0.5973
Ken	-0.2420
Lena	0.0934
Marie	0.3541
Pete	0.3230
Randy	0.0968

Table 7: Deviation from Intercept by **Site**.

	(Intercept)
B1	-0.0569
B2	0.0283
B3	0.0472
B4	-0.0885
B5	0.0977
B6	-0.0277
Y1	-0.0721
Y2	0.0002
Y3	0.0002
Y4	0.0718

Table 8: Deviation from Intercept by **Year**.

	(Intercept)
2013_14	-0.0379
2014_15	0.0451
2015_16	-0.0072

Edge Smell

This analysis investigates whether the scores varied between rivers (River) and among seasons (Time), while accounting for the random effects of Elder, Site and Year on the Intercept (i.e. mean score). The steps for the analysis were:

1. Fit a model with an interaction between River and Time.
2. Assess model residuals visually (not shown but codes for plots available in the txt file).
3. Run marginal tests for testing the significance of the interaction.
   - If the interaction was significant at $\alpha = 0.05$, the full model was used for inference.
   - If the interaction was not significant at $\alpha = 0.05$, the interaction was removed and the model was re-fitted with main effects only.
4. Conduct multiple comparison tests (Tukey's test) if the Interaction or effect of Season were found to be significant at $\alpha = 0.05$.

Marginal tests of significance applied to the full model for **Edge Smell** revealed that the interaction term was significant (Table 1). Therefore, the full model was retained for inference. Estimates for individual fixed effects are presented in Table 2.

Table 1: Marginal tests of significance for full model of **Edge Smell**.

	numDF	denDF	F-value	p-value
(Intercept)	1	802	119.53	0.00
Time	3	802	3.65	0.01
River	1	802	9.02	0.00
Time:River	3	802	7.99	0.00

Table 2: Estimates of fixed effects in the model for **Edge Smell** with associated standard error (SE), degrees of freedom (DF), t-test statistic and p-value.

	Value	SE	DF	t-value	p-value
(Intercept)	2.7527	0.2741	802	10.0423	0.0000
TimeT2	-0.3016	0.1103	802	-2.7349	0.0064
TimeT3	-0.2909	0.1092	802	-2.6644	0.0079
TimeT4	-0.3097	0.1145	802	-2.7059	0.0070
RiverYalakom	0.4833	0.1661	802	2.9093	0.0037
TimeT2:RiverYalakom	0.5190	0.1749	802	2.9680	0.0031
TimeT3:RiverYalakom	0.3144	0.1737	802	1.8105	0.0706
TimeT4:RiverYalakom	-0.2822	0.1770	802	-1.5941	0.1113

Multiple comparisons between seasons within a river showed the following significant differences (see detailed results in Table 3 and Figure 1):

- Bridge River
  - No significant differences.
- Yalakom River
  - Scores in T4 were **smaller** than in T1, T2, and T3

Table 3: Multiple comparisons of scores between seasons within a river. H0 denotes the null hypothesis being tested (i.e. difference equal to 0).

Contrast	H0	Estimate	SE	Test Statistic	p-value
T1.Bridge - T2.Bridge	0	0.3016	0.1103	2.7349	0.0624
T1.Bridge - T3.Bridge	0	0.2909	0.1092	2.6644	0.0758
T1.Bridge - T4.Bridge	0	0.3097	0.1145	2.7059	0.0676
T2.Bridge - T3.Bridge	0	-0.0107	0.1080	-0.0992	1.0000
T2.Bridge - T4.Bridge	0	0.0081	0.1136	0.0714	1.0000
T3.Bridge - T4.Bridge	0	0.0188	0.1125	0.1673	1.0000
T1.Yalakom - T2.Yalakom	0	-0.2174	0.1362	-1.5959	0.6166
T1.Yalakom - T3.Yalakom	0	-0.0235	0.1367	-0.1717	1.0000
T1.Yalakom - T4.Yalakom	0	0.5919	0.1356	4.3643	0.0002
T2.Yalakom - T3.Yalakom	0	0.1939	0.1363	1.4221	0.7351
T2.Yalakom - T4.Yalakom	0	0.8093	0.1357	5.9644	0.0000
T3.Yalakom - T4.Yalakom	0	0.6154	0.1339	4.5946	0.0001

Multiple comparisons between rivers within a season showed the following significant differences (see detailed results in Table 4 and Figure 1):

- T1
  - Scores in the Yalakom River were **greater** than in the Bridge River
- T2
  - Scores in the Yalakom River were **greater** than in the Bridge River
- T3
  - Scores in the Yalakom River were **greater** than in the Bridge River
- T4
  - No signficant difference in scores between Rivers.

Table 4: Multiple comparisons of scores between rivers within a season. H0 denotes the null hypothesis being tested (i.e. difference equal to 0).

Contrast	H0	Estimate	SE	Test Statistic	p-value
T1.Yalakom - T1.Bridge	0	0.4833	0.1661	2.9093	0.0137
T2.Yalakom - T2.Bridge	0	1.0024	0.1656	6.0534	0.0000
T3.Yalakom - T3.Bridge	0	0.7977	0.1643	4.8554	0.0000
T4.Yalakom - T4.Bridge	0	0.2012	0.1678	1.1986	0.5853

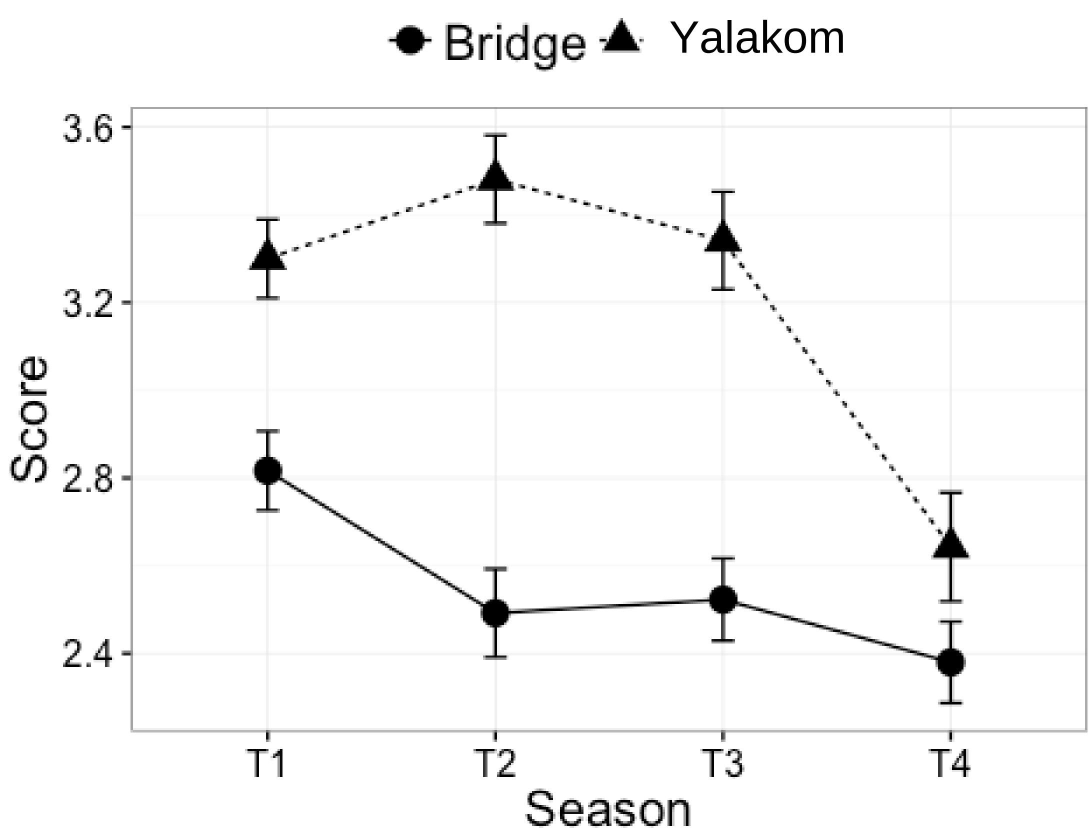


Figure 1: Interaction plot showing mean scores (± 1SE) for **Edge Smell** by river and season.

A much larger amount of the variability in scores for **Edge Smell** was associated with Elders, with about 4 and 6 times as much variation in scores among Elders than among Sites or Years, respectively (see SD in Table 5).

Table 5: Standard deviation (SD) estimates for the random effects of Elder, Site and Year in the model for **Edge Smell**.

Random Effect	SD
Elder	0.7169
Site	0.1712
Year	0.1185
Residual	0.8592

An estimate of how much the Intercept (equivalent to mean score) changed by Elder, Site and Year is provided in Tables 6, 7, and 8, respectively. Positive and negative values mean the scores given are consistently above or below average (i.e. Intercept), respectively.

Table 6: Deviation from Intercept by **Elder**.

	(Intercept)
Aggie	0.0834
Albert	0.3574
Carl	0.2615
Eugene	-1.8426
Gasper	-0.3066
Ken	-0.0349
Lena	0.1186
Marie	0.7449
Pete	0.3261
Randy	0.2920

Table 7: Deviation from Intercept by **Site**.

	(Intercept)
B1	-0.2189
B2	-0.1128
B3	-0.0986
B4	0.0097
B5	0.1415
B6	0.2791
Y1	-0.0209
Y2	0.0686
Y3	0.0224
Y4	-0.0701

Table 8: Deviation from Intercept by **Year**.

	(Intercept)
2013_14	-0.1161
2014_15	0.0194
2015_16	0.0967

Movement

This analysis investigates whether the scores varied between rivers (River) and among seasons (Time), while accounting for the random effects of Elder, Site and Year on the Intercept (i.e. mean score). The steps for the analysis were:

1. Fit a model with an interaction between River and Time.
2. Assess model residuals visually (not shown but codes for plots available in the txt file).
3. Run marginal tests for testing the significance of the interaction.
    - If the interaction was significant at $\alpha = 0.05$, the full model was used for inference.
    - If the interaction was not significant at $\alpha = 0.05$, the interaction was removed and the model was re-fitted with main effects only.
4. Conduct multiple comparison tests (Tukey's test) if the Interaction or effect of Season were found to be significant at $\alpha = 0.05$.

Marginal tests of significance applied to the full model for **Movement** revealed that the interaction term was significant (Table 1). Therefore, the full model was retained for inference. Estimates for individual fixed effects are presented in Table 2.

Table 1: Marginal tests of significance for full model of **Movement**.

	numDF	denDF	F-value	p-value
(Intercept)	1	803	314.61	0.00
Time	3	803	3.50	0.02
River	1	803	2.49	0.11
Time:River	3	803	3.00	0.03

Table 2: Estimates of fixed effects in the model for **Movement** with associated standard error (SE), degrees of freedom (DF), t-test statistic and p-value.

	Value	SE	DF	t_value	P
(Intercept)	3.1356	0.1983	803	15.8147	0.0000
TimeT2	-0.1955	0.0983	803	-1.9888	0.0471
TimeT3	0.0904	0.0974	803	0.9277	0.3538
TimeT4	-0.1318	0.1022	803	-1.2890	0.1978
RiverYalakom	0.3042	0.2032	803	1.4968	0.1348
TimeT2:RiverYalakom	0.3311	0.1562	803	2.1198	0.0343
TimeT3:RiverYalakom	-0.1156	0.1552	803	-0.7452	0.4564
TimeT4:RiverYalakom	0.0326	0.1581	803	0.2059	0.8369

Multiple comparisons between seasons within a river showed the following significant differences (see detailed results in Table 3 and Figure 1):

- Bridge River
  - Scores in T3 were **greater** than in T2
- Yalakom River
  - No significant differences

Table 3: Multiple comparisons of scores between seasons within a river. H0 denotes the null hypothesis being tested (i.e. difference equal to 0).

Contrast	H0	Estimate	SE	Test Statistic	P
T1.Bridge - T2.Bridge	0	0.1955	0.0983	1.9888	0.3472
T1.Bridge - T3.Bridge	0	-0.0904	0.0974	-0.9277	0.9559
T1.Bridge - T4.Bridge	0	0.1318	0.1022	1.2890	0.8150
T2.Bridge - T3.Bridge	0	-0.2858	0.0963	-2.9689	0.0314
T2.Bridge - T4.Bridge	0	-0.0637	0.1013	-0.6286	0.9940
T3.Bridge - T4.Bridge	0	0.2221	0.1005	2.2113	0.2257
T1.Yalakom - T2.Yalakom	0	-0.1356	0.1216	-1.1153	0.8976
T1.Yalakom - T3.Yalakom	0	0.0253	0.1219	0.2073	1.0000
T1.Yalakom - T4.Yalakom	0	0.0992	0.1211	0.8194	0.9761
T2.Yalakom - T3.Yalakom	0	0.1609	0.1217	1.3219	0.7964
T2.Yalakom - T4.Yalakom	0	0.2348	0.1211	1.9392	0.3784
T3.Yalakom - T4.Yalakom	0	0.0739	0.1196	0.6182	0.9946

Multiple comparisons between rivers within a season showed the following significant differences (see detailed results in Table 4 and Figure 1):

- T1
  - No signficant difference in scores between Rivers.
- T2
  - Scores in the Yalakom River were **greater** than in the Bridge River
- T3
  - No signficant difference in scores between Rivers.
- T4
  - No signficant difference in scores between Rivers.

Table 4: Multiple comparisons of scores between rivers within a season. H0 denotes the null hypothesis being tested (i.e. difference equal to 0).

Contrast	H0	Estimate	SE	Test Statistic	P
T1.Yalakom - T1.Bridge	0	0.3042	0.2032	1.4968	0.3092
T2.Yalakom - T2.Bridge	0	0.6353	0.2028	3.1332	0.0060
T3.Yalakom - T3.Bridge	0	0.1885	0.2020	0.9334	0.6749
T4.Yalakom - T4.Bridge	0	0.3367	0.2042	1.6488	0.2379

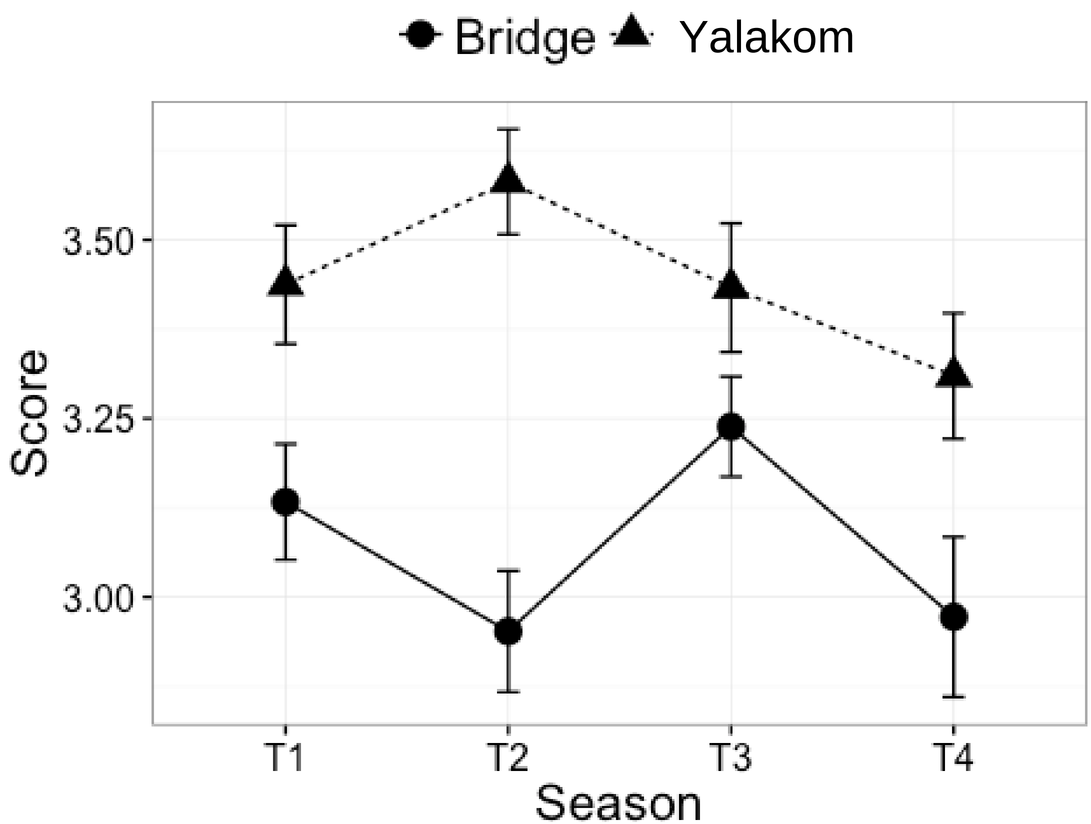


Figure 1: Interaction plot showing mean scores (± 1SE) for **Movement** by river and season.

There was about 1.5 times as much variation in scores among Elders than among Sites (see SD in Table 5). There was virtually no variation in mean scores among years (Table 5).

Table 5: Standard deviation (SD) estimates for the random effects of Elder, Site and Year in the model for **Movement**.

Random Effect	SD
Elder	0.4075
Site	0.2638
Year	0.0000
Residual	0.7681

An estimate of how much the Intercept (equivalent to mean score) changed by Elder, Site and Year is provided in Tables 6, 7, and 8, respectively. Positive and negative values mean the scores given are consistently above or below average (i.e. Intercept), respectively.

Table 6: Deviation from Intercept by **Elder**.

	(Intercept)
Aggie	-0.3006
Albert	0.2829
Carl	0.2173
Eugene	-0.7712
Gasper	0.3797
Ken	-0.3587
Lena	0.3808
Marie	0.3544
Pete	-0.0784
Randy	-0.1062

Table 7: Deviation from Intercept by **Site**.

	(Intercept)
B1	-0.5305
B2	0.0059
B3	-0.1841
B4	0.1624
B5	0.2406
B6	0.3057
Y1	-0.0092
Y2	0.0778
Y3	0.0012
Y4	-0.0698

Table 8: Deviation from Intercept by **Year**.

	(Intercept)
2013_14	0
2014_15	0
2015_16	0

Smell

This analysis investigates whether the scores varied between rivers (River) and among seasons (Time), while accounting for the random effects of Elder, Site and Year on the Intercept (i.e. mean score). The steps for the analysis were:

1. Fit a model with an interaction between River and Time.
2. Assess model residuals visually (not shown but codes for plots available in the txt file).
3. Run marginal tests for testing the significance of the interaction.
   - If the interaction was significant at $\alpha = 0.05$, the full model was used for inference.
   - If the interaction was not significant at $\alpha = 0.05$, the interaction was removed and the model was re-fitted with main effects only.
4. Conduct multiple comparison tests (Tukey's test) if the Interaction or effect of Season were found to be significant at $\alpha = 0.05$.

Marginal tests of significance applied to the full model for **Smell** revealed that the interaction term was significant (Table 1). Therefore, the full model was retained for inference. Estimates for individual fixed effects are presented in Table 2.

Table 1: Marginal tests of significance for full model of **Smell**.

	numDF	denDF	F-value	p-value
(Intercept)	1	803	119.77	0.00
Time	3	803	4.68	0.00
River	1	803	5.24	0.02
Time:River	3	803	6.78	0.00

Table 2: Estimates of fixed effects in the model for **Smell** with associated standard error (SE), degrees of freedom (DF), t-test statistic and p-value.

	Value	SE	DF	t-value	p-value
(Intercept)	2.7649	0.2765	803	9.9987	0.0000
TimeT2	-0.2995	0.1174	803	-2.5506	0.0109
TimeT3	-0.2864	0.1165	803	-2.4593	0.0141
TimeT4	-0.4406	0.1221	803	-3.6079	0.0003
RiverYalakom	0.3958	0.1787	803	2.2148	0.0271
TimeT2:RiverYalakom	0.6281	0.1864	803	3.3696	0.0008
TimeT3:RiverYalakom	0.3934	0.1853	803	2.1237	0.0340
TimeT4:RiverYalakom	-0.1144	0.1888	803	-0.6058	0.5448

Multiple comparisons between seasons within a river showed the following significant differences (see detailed results in Table 3 and Figure 1):

- Bridge River
  - Scores in T4 were **smaller** than in T1
- Yalakom River
  - Scores in T4 were **smaller** than in T1, T2 and T3

Table 3: Multiple comparisons of scores between seasons within a river. H0 denotes the null hypothesis being tested (i.e. difference equal to 0).

Contrast	H0	Estimate	SE	Test Statistic	P
T1.Bridge - T2.Bridge	0	0.2995	0.1174	2.5506	0.1021
T1.Bridge - T3.Bridge	0	0.2864	0.1165	2.4593	0.1285
T1.Bridge - T4.Bridge	0	0.4406	0.1221	3.6079	0.0035
T2.Bridge - T3.Bridge	0	-0.0131	0.1150	-0.1136	1.0000
T2.Bridge - T4.Bridge	0	0.1411	0.1209	1.1667	0.8760
T3.Bridge - T4.Bridge	0	0.1542	0.1200	1.2851	0.8171
T1.Yalakom - T2.Yalakom	0	-0.3286	0.1453	-2.2616	0.2027
T1.Yalakom - T3.Yalakom	0	-0.1070	0.1459	-0.7335	0.9865
T1.Yalakom - T4.Yalakom	0	0.5550	0.1447	3.8362	0.0014
T2.Yalakom - T3.Yalakom	0	0.2216	0.1454	1.5241	0.6669
T2.Yalakom - T4.Yalakom	0	0.8836	0.1447	6.1051	0.0000
T3.Yalakom - T4.Yalakom	0	0.6620	0.1429	4.6327	0.0000

Multiple comparisons between rivers within a season showed the following significant differences (see detailed results in Table 4 and Figure 1):

- T1
  - No signficant difference in scores between Rivers.
- T2
  - Scores in the Yalakom River were **greater** than in the Bridge River
- T3
  - Scores in the Yalakom River were **greater** than in the Bridge River
- T4
  - No signficant difference in scores between Rivers.

Table 4: Multiple comparisons of scores between rivers within a season. H0 denotes the null hypothesis being tested (i.e. difference equal to 0).

Contrast	H0	Estimate	SE	Test Statistic	P
T1.Yalakom - T1.Bridge	0	0.3958	0.1787	2.2148	0.0905
T2.Yalakom - T2.Bridge	0	1.0240	0.1780	5.7532	0.0000
T3.Yalakom - T3.Bridge	0	0.7893	0.1768	4.4648	0.0000
T4.Yalakom - T4.Bridge	0	0.2814	0.1805	1.5592	0.3438

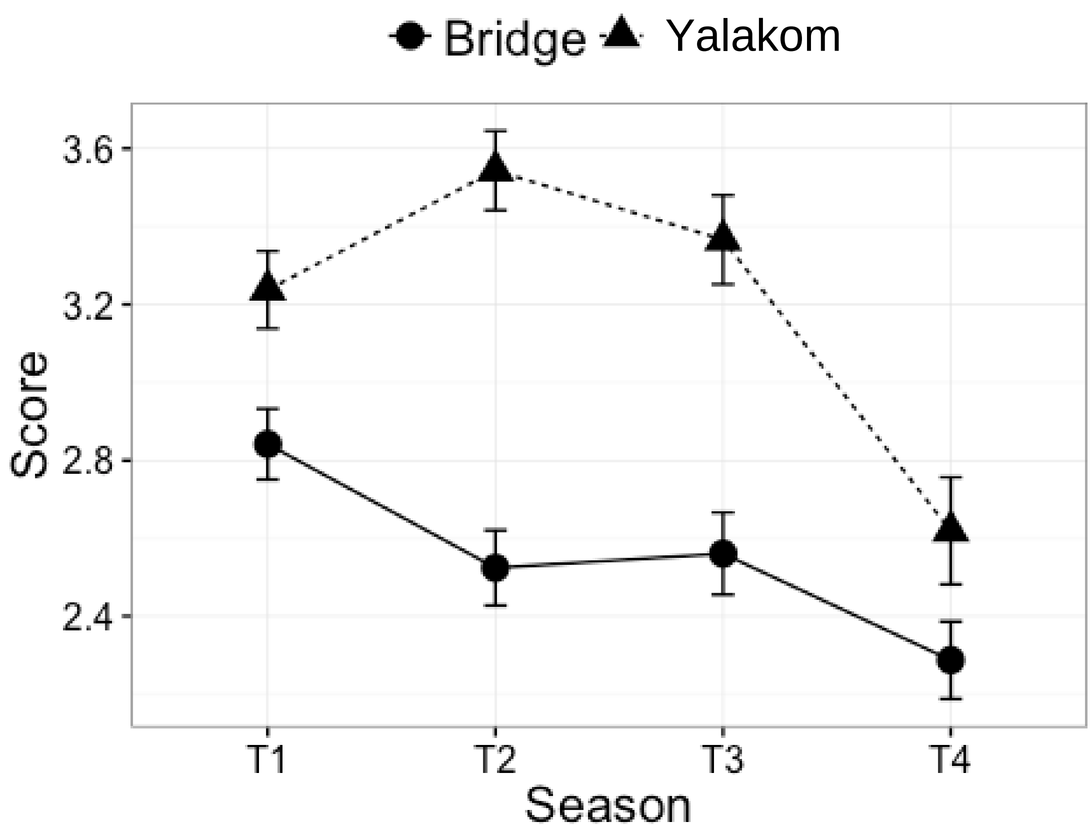


Figure 1: Interaction plot showing mean scores (± 1SE) for **Smell** by river and season.

A much larger amount of the variability in scores for **Smell** was associated with Elders, with about 4 and 6 times as much variation in scores among Elders than among Sites or Years, respectively (see SD in Table 5).

Table 5: Standard deviation (SD) estimates for the random effects of Elder, Site and Year in the model for **Smell**.

Random Effect	SD
Elder	0.7075
Site	0.1861
Year	0.1166
Residual	0.9167

An estimate of how much the Intercept (equivalent to mean score) changed by Elder, Site and Year is provided in Tables 6, 7, and 8, respectively. Positive and negative values mean the scores given are consistently above or below average (i.e. Intercept), respectively.

Table 6: Deviation from Intercept by **Elder**.

	(Intercept)
Aggie	0.0563
Albert	0.4002
Carl	0.1587
Eugene	-1.8504
Gasper	-0.2691
Ken	-0.0042
Lena	0.3173
Marie	0.5731
Pete	0.3713
Randy	0.2468

Table 7: Deviation from Intercept by **Site**.

	(Intercept)
B1	-0.2123
B2	-0.1173
B3	-0.1553
B4	0.0157
B5	0.1487
B6	0.3206
Y1	0.0187
Y2	0.0497
Y3	-0.0342
Y4	-0.0342

Table 8: Deviation from Intercept by **Year**.

	(Intercept)
2013_14	-0.1206
2014_15	0.0553
2015_16	0.0652

Voice

This analysis investigates whether the scores varied between rivers (River) and among seasons (Time), while accounting for the random effects of Elder, Site and Year on the Intercept (i.e. mean score). The steps for the analysis were:

1. Fit a model with an interaction between River and Time.
2. Assess model residuals visually (not shown but codes for plots available in the txt file).
3. Run marginal tests for testing the significance of the interaction.
   - If the interaction was significant at $\alpha = 0.05$, the full model was used for inference.
   - If the interaction was not significant at $\alpha = 0.05$, the interaction was removed and the model was re-fitted with main effects only.
4. Conduct multiple comparison tests (Tukey's test) if the Interaction or effect of Season were found to be significant at $\alpha = 0.05$.

Marginal tests of significance applied to the full model for **Voice** revealed that the interaction term was not significant (Table 1). The same test was run on the model re-fitted with main effects only, revealing that the scores assigned to the Yalakom River were significantly greater than those assigned to the Bridge River (Tables 2 and 3; Figure 1).

Table 1: Marginal tests of significance for full model of **Voice**.

	numDF	denDF	F-value	p-value
(Intercept)	1	802	383.95	0.00
Time	3	802	1.43	0.23
River	1	802	3.38	0.07
Time:River	3	802	1.06	0.36

Table 2: Marginal tests of significance for model of **Voice** containing only the main effects.

	numDF	denDF	F-value	p-value
(Intercept)	1	805	392.55	0.00
River	1	805	8.22	0.00
Time	3	805	2.31	0.07

Table 3: Estimates of fixed effects in the model for **Voice** with associated standard error (SE), degrees of freedom (DF), t-test statistic and p-value.

	Value	SE	DF	t-value	p-value
(Intercept)	3.1029	0.1767	805	17.5632	0.0000
RiverYalakom	0.4080	0.1526	805	2.6731	0.0077
TimeT2	0.0555	0.0702	805	0.7899	0.4298
TimeT3	0.1779	0.0701	805	2.5363	0.0114
TimeT4	0.1047	0.0717	805	1.4596	0.1448

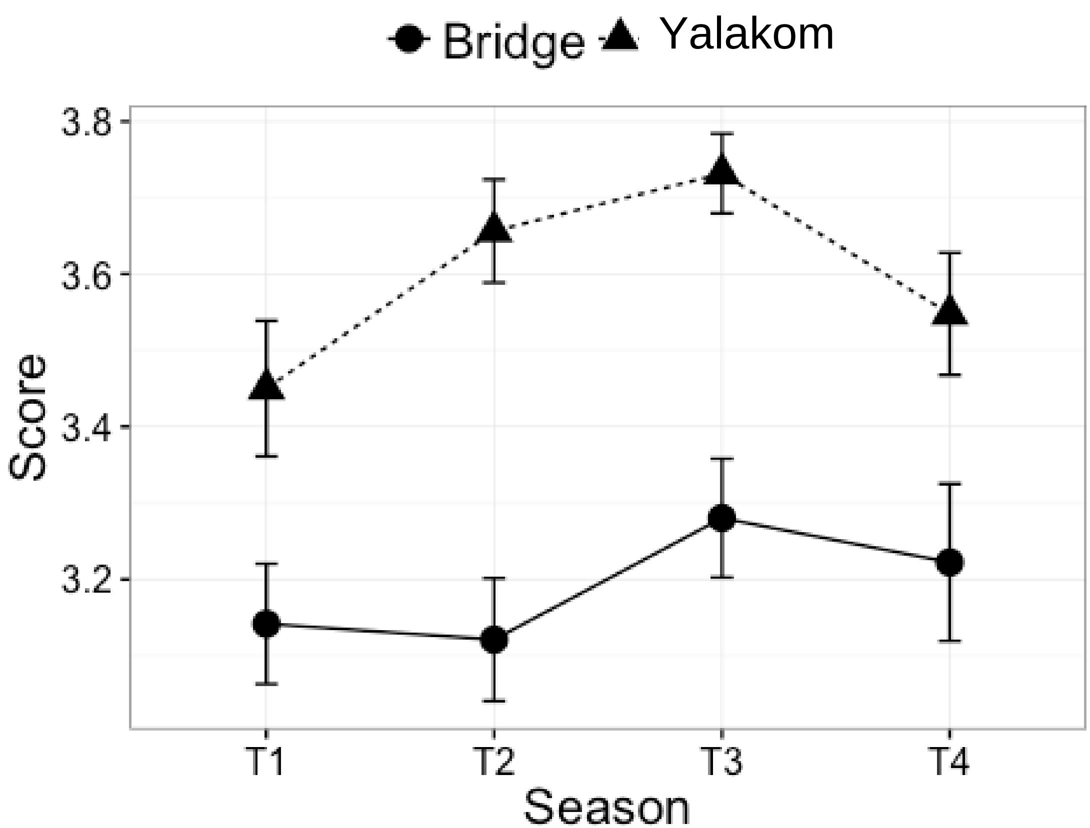


Figure 1: Interaction plot showing mean scores (± 1SE) for **Voice** by river and season.

There was about 1.7 times as much variation in scores among Elders than among Sites (see SD in Table 4).There was virtually no variation in mean scores among years (Table 4).

Table 4: Standard deviation (SD) estimates for the random effects of Elder, Site and Year in the model for **Voice**.

Random Effect	SD
Elder	0.3837
Site	0.2230
Year	0.0000
Residual	0.7039

An estimate of how much the Intercept (equivalent to mean score) changed by Elder, Site and Year is provided in Tables 5, 6, and 7, respectively. Positive and negative values mean the scores given are consistently above or below average (i.e. Intercept), respectively.

Table 5: Deviation from Intercept by **Elder**.

	(Intercept)
Aggie	-0.6274
Albert	0.3450
Carl	0.1134
Eugene	-0.4286
Gasper	0.3500
Ken	-0.3896
Lena	0.4605
Marie	0.1144
Pete	-0.0442
Randy	0.1065

Table 6: Deviation from Intercept by **Site**.

	(Intercept)
B1	-0.4392
B2	-0.0284
B3	-0.0999
B4	0.2574
B5	0.1475
B6	0.1627
Y1	-0.1178
Y2	-0.0324
Y3	0.1450
Y4	0.0052

Table 7: Deviation from Intercept by **Year**.

	(Intercept)
2013_14	0
2014_15	0
2015_16	0

Wadeability

This analysis investigates whether the scores varied between rivers (River) and among seasons (Time), while accounting for the random effects of Elder, Site and Year on the Intercept (i.e. mean score). The steps for the analysis were:

1. Fit a model with an interaction between River and Time.
2. Assess model residuals visually (not shown but codes for plots available in the Rmd file).
3. Run marginal tests for testing the significance of the interaction.
   - If the interaction was significant at $\alpha = 0.05$, the full model was used for inference.
   - If the interaction was not significant at $\alpha = 0.05$, the interaction was removed and the model was re-fitted with main effects only.
4. Conduct multiple comparison tests (Tukey's test) if the Interaction or effect of Season were found to be significant at $\alpha = 0.05$.

Marginal tests of significance applied to the full model for **Wadeability** revealed that the interaction term was significant (Table 1). Therefore, the full model was retained for inference. Estimates for individual fixed effects are presented in Table 2.

Table 1: Marginal tests of significance for full model of **Wadeability**.

	numDF	denDF	F-value	p-value
(Intercept)	1	803	18.22	0.00
Time	3	803	21.58	0.00
River	1	803	0.17	0.68
Time:River	3	803	12.26	0.00

Table 2: Estimates of fixed effects in the model for **Wadeability** with associated standard error (SE), degrees of freedom (DF), t-test statistic and p-value.

	Value	SE	DF	t-value	p-value
(Intercept)	0.9512	0.2546	803	3.7367	0.0002
TimeT2	0.5613	0.1382	803	4.0626	0.0001
TimeT3	-0.0985	0.1369	803	-0.7201	0.4717
TimeT4	-0.5737	0.1437	803	-3.9927	0.0001
RiverYalakom	0.1125	0.2890	803	0.3892	0.6972
TimeT2:RiverYalakom	-0.4249	0.2196	803	-1.9350	0.0533
TimeT3:RiverYalakom	0.8547	0.2181	803	3.9188	0.0001
TimeT4:RiverYalakom	-0.0031	0.2221	803	-0.0138	0.9890

Multiple comparisons between seasons within a river showed the following significant differences (see detailed results in Table 3 and Figure 1):

- Bridge River
  - Scores in T4 were **smaller** than in T1, T2, and T3
  - Scores in T2 were **greater** than in T1 and T3
- Yalakom River
  - Scores in T4 were **smaller** than in T1, T2, and T3
  - Scores in T3 were **greater** than in T1 and T2

Table 3: Multiple comparisons of scores between seasons within a river. H0 denotes the null hypothesis being tested (i.e. difference equal to 0).

Contrast	H0	Estimate	SE	Test Statistic	p-value
T1.Bridge - T2.Bridge	0	-0.5613	0.1382	-4.0626	0.0006
T1.Bridge - T3.Bridge	0	0.0985	0.1369	0.7201	0.9877
T1.Bridge - T4.Bridge	0	0.5737	0.1437	3.9927	0.0008
T2.Bridge - T3.Bridge	0	0.6598	0.1353	4.8777	0.0000
T2.Bridge - T4.Bridge	0	1.1350	0.1424	7.9697	0.0000
T3.Bridge - T4.Bridge	0	0.4752	0.1411	3.3670	0.0084
T1.Yalakom - T2.Yalakom	0	-0.1364	0.1709	-0.7980	0.9791
T1.Yalakom - T3.Yalakom	0	-0.7561	0.1712	-4.4163	0.0001
T1.Yalakom - T4.Yalakom	0	0.5768	0.1700	3.3923	0.0077
T2.Yalakom - T3.Yalakom	0	-0.6197	0.1709	-3.6251	0.0033
T2.Yalakom - T4.Yalakom	0	0.7132	0.1701	4.1937	0.0003
T3.Yalakom - T4.Yalakom	0	1.3329	0.1681	7.9283	0.0000

Multiple comparisons between rivers within a season showed the following significant differences (see detailed results in Table 4 and Figure 1):

- T1
  - No significant difference in scores between Rivers
- T2
  - No significant difference in scores between Rivers
- T3
  - Scores in the Yalakom River were **greater** than in the Bridge River
- T4
  - No significant difference in scores between Rivers

Table 4: Multiple comparisons of scores between rivers within a season. H0 denotes the null hypothesis being tested (i.e. difference equal to 0).

Contrast	H0	Estimate	SE	Test Statistic	p-value
T1.Yalakom - T1.Bridge	0	0.1125	0.2890	0.3892	0.9739
T2.Yalakom - T2.Bridge	0	-0.3124	0.2884	-1.0832	0.5624
T3.Yalakom - T3.Bridge	0	0.9672	0.2873	3.3669	0.0026
T4.Yalakom - T4.Bridge	0	0.1094	0.2903	0.3769	0.9767

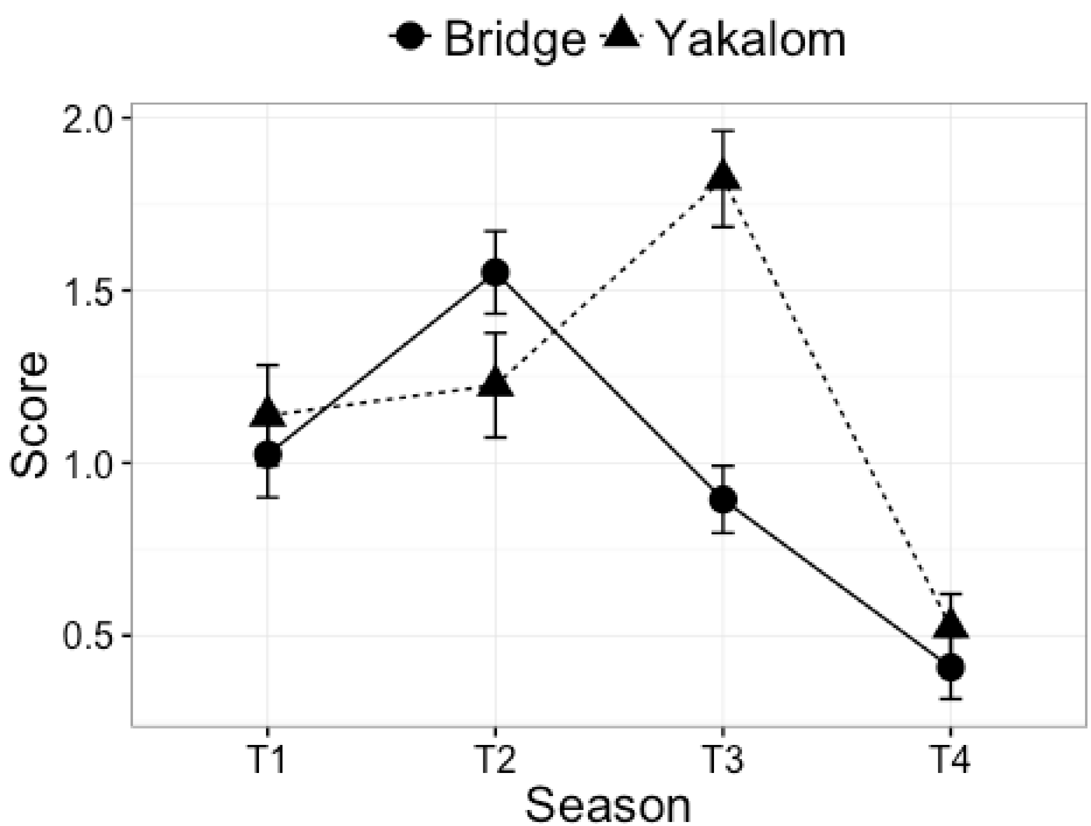


Figure 1: Interaction plot showing mean scores (± 1SE) for **Wadeability** by river and season.

There was as much variation in scores among Elders as among Sites (see SD in Table 5). There was virtually no variation in mean scores among years (Table 5).

Table 5: Standard deviation (SD) estimates for the random effects of Elder, Site and Year in the model for **Wadeability**.

Random Effect	SD
Elder	0.4402
Site	0.3771
Year	0.0000
Residual	1.0798

An estimate of how much the Intercept (equivalent to mean score) changed by Elder, Site and Year is provided in Tables 6, 7, and 8, respectively. Positive and negative values mean the scores given are consistently above or below average (i.e. Intercept), respectively.

Table 5: Deviation from Intercept by **Elder**.

	(Intercept)
Aggie	0.7781
Albert	-0.0778
Carl	0.3160
Eugene	-0.4045
Gasper	-0.6622
Ken	0.0172
Lena	-0.3857
Marie	0.0863
Pete	0.1327
Randy	0.1999

Table 6: Deviation from Intercept by **Site**.

	(Intercept)
B1	0.3238
B2	0.0043
B3	0.4247
B4	-0.4105
B5	0.0324
B6	-0.3748
Y1	0.2907
Y2	0.3618
Y3	-0.2577
Y4	-0.3948

Table 7: Deviation from Intercept by **Year**.

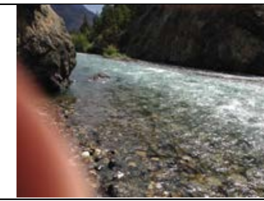
	(Intercept)
2013_14	0
2014_15	0
2015_16	0

Appendix 2: Photos

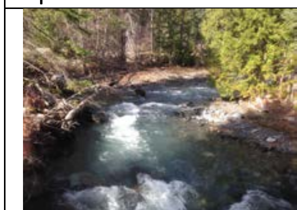
August 10 -11, 2015

B1	B2	B3	B4	B5	B6
Upstream					
					
Upstream					
					
Y1	Y2	Y3	Y4		

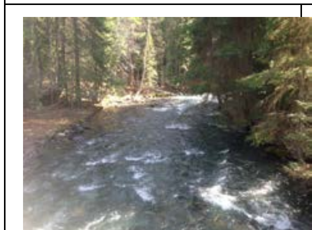
August 10-11, 2015

B1	B2	B3	B4	B5	B6
Downstream					
					
Downstream					
					
Y1	Y2	Y3	Y4		

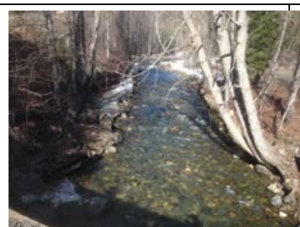
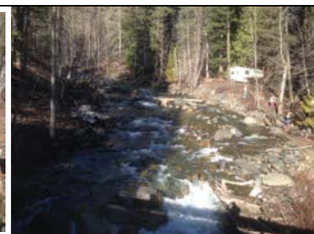
October 14-15, 2015

B1	B2	B3	B4	B5	B6
Upstream					
					
Upstream					
					
Y1	Y2	Y3	Y4		

October 14-15, 2015

B1	B2	B3	B4	B5	B6
Downstream					
					
Downstream					
					
Y1	Y2	Y3	Y4		

March 14-15, 2016

B1	B2	B3	B4	B5	B6
Upstream					
					
Upstream					
					
Y1	Y2	Y3	Y4		

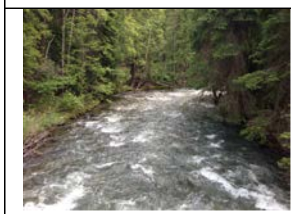
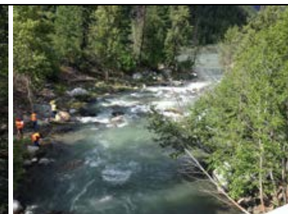
March 14-15, 2016

B1	B2	B3	B4	B5	B6
Downstream					
					
Downstream					
					
Y1	Y2	Y3	Y4		

June 1-2, 2016

B1	B2	B3	B4	B5	B6
Upstream					
					
Upstream					
					
Y1	Y2	Y3	Y4		

June 1-2, 2016

B1	B2	B3	B4	B5	B6
Downstream					
					
Downstream					
					
Y1	Y2	Y3	Y4		