Assessing the effect of climate change on flow regime characteristics

W. Kyle Hamilton[1], Mark Poesch[1], Andrew Paul[2], Caroline Bampfylde[2], and Eva Enders[3]

Department of Renewable Resources, University of Alberta[1], Alberta Environment and Sustainable Resource Department[2], Department of Fisheries and Oceans[3]

Introduction

- Fish life history structure is largely dependent on flow regime characteristics of streams and rivers [1].
- Habitat for aquatic and riparian species is modified as a result of flow alteration, which can impact the magnitude, variability and frequency of flows [2]. Two major causes of flow alteration are land use practices and climate change [3, 4].
- Therefore, it is important to understand the ecological impacts of water extraction on stream hydrology.

Objectives

Current:

- Estimate the impact of temperature and precipitation data on trends in flow regime characteristics.

Future:

- Assess the ecological impacts of water extraction on stream hydrology and Alberta's fish community structure and function.

Methods

Daily flow data was obtained from Environment Canada and climate data was generated using the ClimateNA v5.10 software [5, 6]. The Indicators of Hydrologic Alteration (IHA) approach was used to determine hydrologic characteristics [7].

Significant trends in IHA characteristics and climate data were identified using the Mann-Kendall test [8, 9]. The correlation between the trends in annual climate and annual IHA characteristics was explored using non-metric multidimensional scaling (NMDS).

Data was analyzed for the period 1961-2010. Only stations with at least 40 years of data were analyzed for significant trends (184 stations were analyzed in total).

The parameters of the indicators of hydrologic alteration [7].

Parameter Category	Regime Characteristics	Hydrologic Index
Group 1: Monthly Flow Conditions	Magnitude, Timing	Median monthly flows
Group 2: Annual extreme water conditions	Magnitude, Duration	Annual minima 1-day means Annual maxima 1-day means Annual minima 3-day means Annual maxima 3-day means Annual minima 7-day means Annual maxima 7-day means Annual minima 30-day means Annual maxima 30-day means Annual minima 90-day means Annual maxima 90-day means
Group 3: Timing of annual extreme water conditions	Timing	Julian date of annual 1-day max Julian date of annual 1-day min
Group 4: High and low pulses	Magnitude, Frequency, Duration	# of high pulses # of low pulses Mean duration of high pulses Mean duration of low pulses
Group 5: Water condition change rate and frequency	Frequency, Rate of Change	Means of all positive differences between consecutive daily flow values Means of all negative differences between consecutive daily flow values # of rises # of falls

Preliminary Results

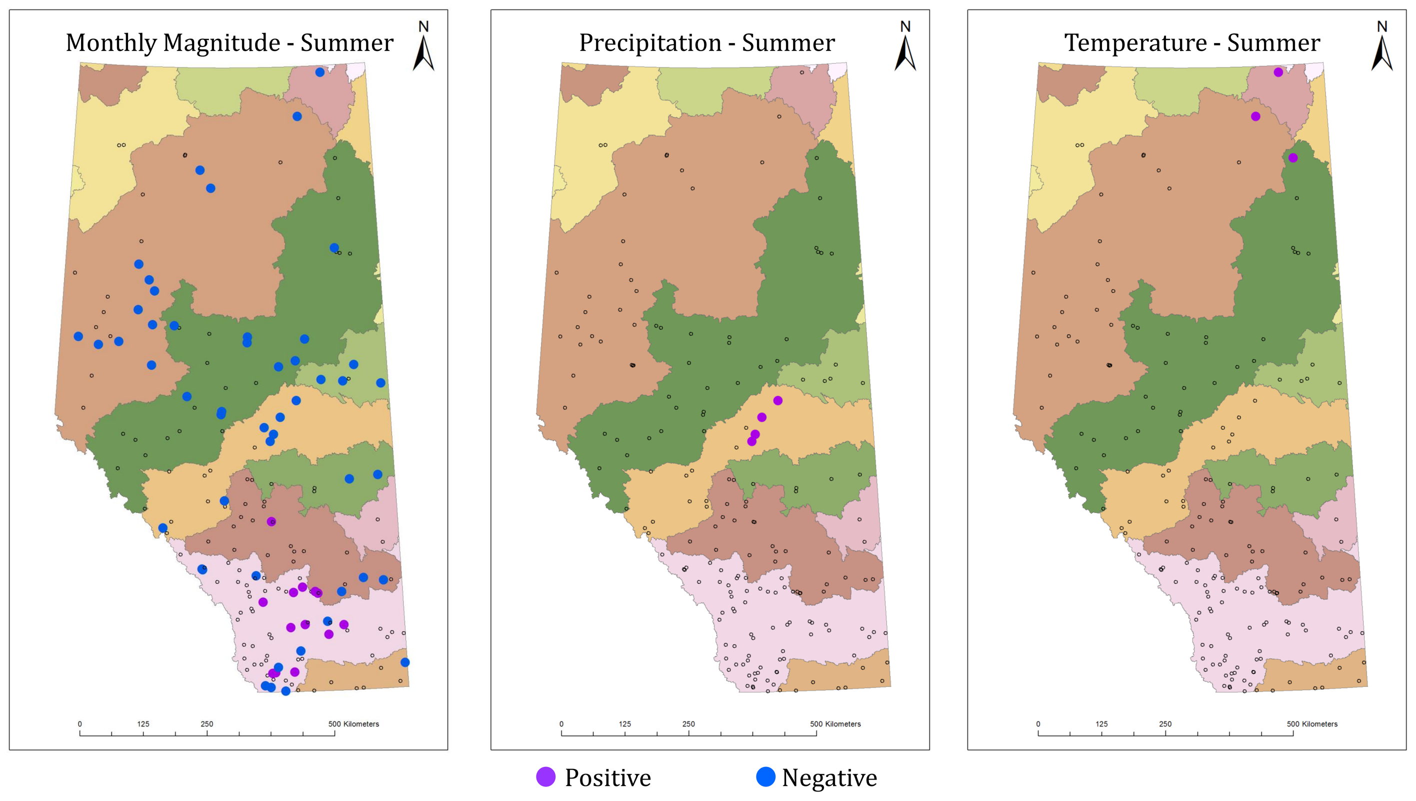
Mann-Kendall:

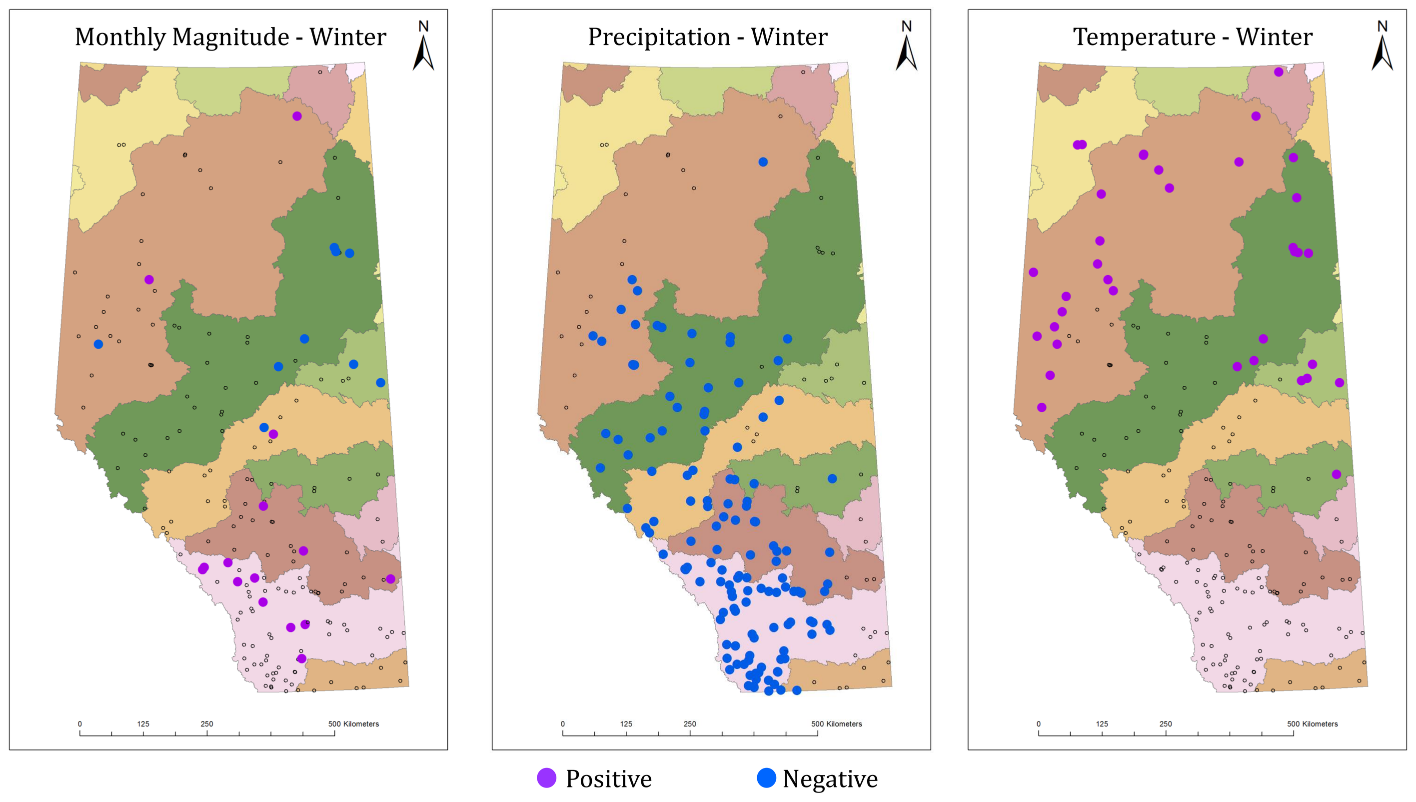
- Significant trends were identified for the 184 rivers at significance values of 0.05 and 0.1 for each season for the summer and winter.

Summary for significant seasonal trends identified by the Mann-Kendall test (P – Positive trends; N – Negative Trends).

Parameter	α level	Summer		Winter		Total
		P	N	P	N	
Monthly Magnitude	0.1	2	15	1	3	21
	0.05	13	49	15	9	86
Precipitation	0.1	24	0	0	24	48
	0.05	4	0	0	131	135
Average Temperature	0.1	7	0	21	0	28
	0.05	3	0	36	0	39

- Significant (α = 0.05) positive flow trends were located mostly in the south, while the negative trends were more prominent in the north. Winter precipitation and temperature were distinctly divided in the south and north, respectively.

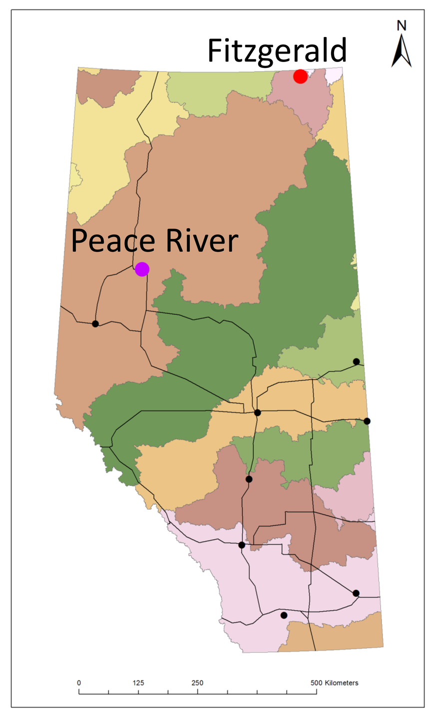




IHA – Case Study

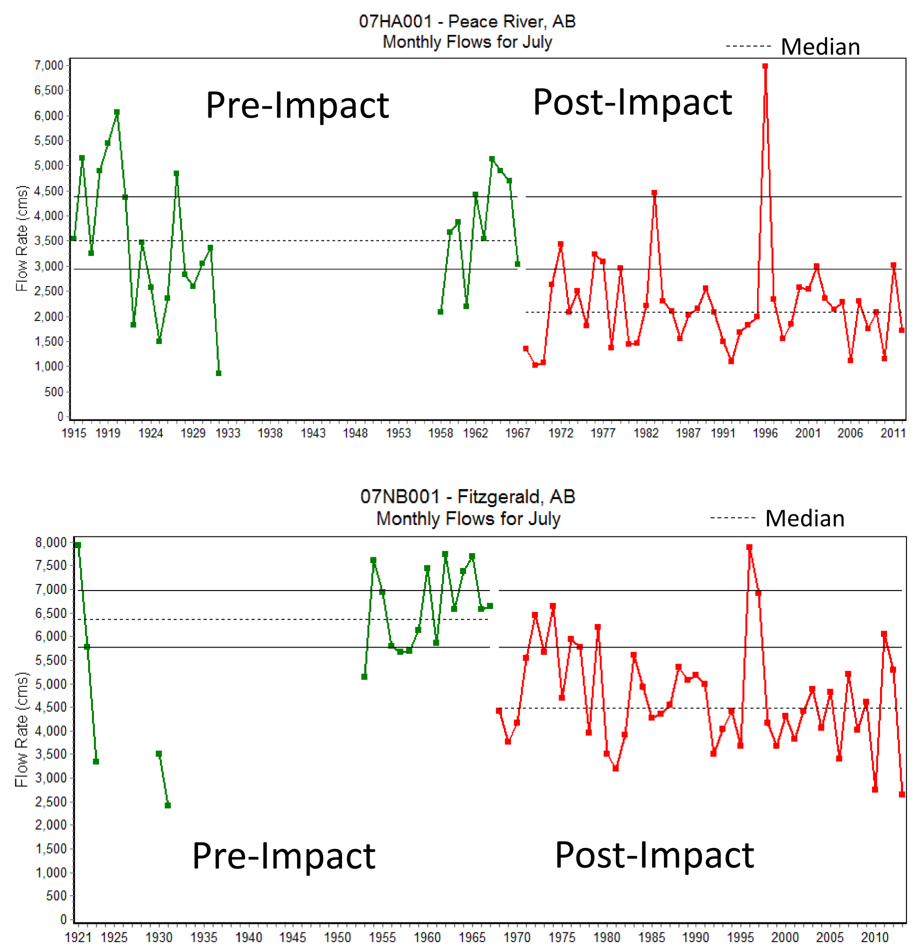
- The flow data at two stations (Peace River and Fitzgerald) were analyzed using the IHA software [10].
- The Fitzgerald Station is on the Slave River.
- The Peace River is a tributary of the Slave River.
- The W.A.C. Bennett Dam is a hydroelectric dam that was built on the Peace River, in northeast British Columbia in 1967 [11].

The locations of the Peace River and Fitzgerald river stations.



Looking at the monthly flow for July, similar trends are observed at both stations. Decrease of the median July flow post-impact is similar at both stations.

Median July monthly flows at both stations, pre- and post-impact.



Resource development upstream of the Fitzgerald station has increased over the last several decades, including oil and gas development, mining, agriculture, forestry, and hydroelectricity [12].

The July hydrographs from the two stations indicate similar impacts as a result of the dam construction. As flows are managed extensively through the dam, the impact from other industries is difficult to ascertain.

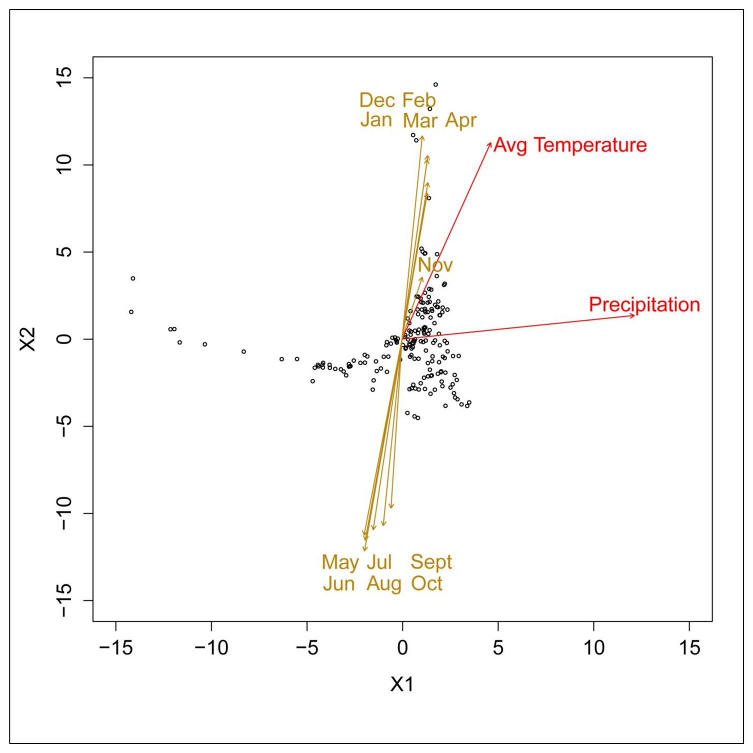
Discussion

Correlation in the trends for several IHA parameter groups are divided seasonally. Trends in monthly flow conditions (Group 1) are divided seasonally in their correlation to average annual temperature: winter months (November to April) are strongly correlated with temperature in a positive direction, while summer months (May to October) are strongly correlated in a negative direction.

The Mann-Kendall results reflect this seasonal contrast, especially in the precipitation and temperature trends.

It is worth noting that winter flow data was less complete than summer flow data.

Spatially, notable separation occurred across the province. The increase in winter temperature in northern Alberta looks like it may potentially have an impact on northern summer flow magnitudes. The cluster of significant positive trends in southern Alberta are curious, given the decrease of winter precipitation and lack of any temperature trends. This will require further investigation.



Future Work:

1. **Water Extraction**: Determining the role of water extraction on the changes in hydrologic flow regime.
2. **Fish Community Structure**: Assess the impact of water extraction on Alberta's freshwater fish community structure.

Acknowledgements

I would like to thank Alberta Innovates – Energy and Environment Solutions for the funding for this project, Andreas Hamann for statistical advice, and the Poesch Lab at the University of Alberta for their technical support.

References

1. Mims, M. C. and J. D. Olden (2012). "Life history theory predicts fish assemblage response to hydrologic regimes." Ecology **93**(1): 35-45.
2. Poff, N. L., et al. (1997). "The natural flow regime." Bioscience **47**(11): 769-784.
3. Sala, O. E., et al. (2010). "Global Biodiversity Scenarios for the Year 2100." Science **287**: 1770-1774.
4. Schindler, D. W. (2001). "The cumulative effects of climate warming and other human stresses on Canadian freshwaters in the new millennium." Canadian Journal of Fisheries and Aquatic Sciences **58**: 18-29.
5. Climate data was generated using ClimateNA v5.10 software package, available at http://tinyurl.com/ClimateNA, based on methodology described by Hamann et al. (2013).
6. Hamann, A., et al. (2013). "A comprehensive, high-resolution database of historical and projected climate surfaces for western North America." Bulletic of the American Meterological Society **94**: 1307-1309.
7. Richter, B. D., et al. (1996). "A method for assessing hydrologic alteration within ecosystems." Conservation Biology **10**(4): 1163-1174.
8. Mann, H. B. (1945). "Nonparametric tests against trend." Econometrica **13**: 245-259.
9. Kendall, M. G. (1975). Rank correlation methods. London.
10. The Nature Conservancy (2009). Indicators of Hydrologic Alteration (IHA) software.
11. BC Hydro (2015). "W.A.C. BENNETT DAM VISITOR CENTRE." Retrieved March 10, 2015, from https://www.bchydro.com/community/recreation_areas/w_a_c_bennett_dam_visitor_centre.html#History.
12. Aboriginal Affairs and Northern Development (2012). "Report Summary: Slave River." Retrieved March 10, 2015.

Contact Information

W. Kyle Hamilton, 751 General Services Building, Department of Renewable Resources, Edmonton, Alberta, CANADA, T6G 2H1, whamilto@ualberta.ca

Mark Poesch, 751 General Services Building, Department of Renewable Resources, Edmonton, Alberta, CANADA, T6G 2H1, poesch@ualberta.ca

Andrew Paul, 213 - 1 Street West, Cochrane, Alberta, CANADA, T4C 1A5, andrew.paul@gov.ab.ca

Caroline Bampfylde, 9th floor Oxbridge Place, 9820 - 106 Street, Edmonton, Alberta, CANADA, T5K 2J6, caroline.bampfylde@gov.ab.ca

Eva Enders, 501 University Crescent Winnipeg, Manitoba, CANADA, R3T 2N6, Eva.Enders@dfo-mpo.gc.ca