Supplemental Tables and Figures

Scott RW, Sharma S, Wang X & Quinlan R. 2022. The limnological response of Arctic deltaic lakes to alterations in flood regime. *Inland Waters* doi: 10.1080/20442041.2022.2030628

Supplemental Table S1 – Water quality parameter (particulates, nutrients, and major ions) mean values by closure type, with results of ANOVAs between closure types. Asterisks (*) denote variables with significant differences in closure type (p < 0.05).

	Units	**High**	**Low**	**No**	**Channel**	**Transform.**	***F***	***p*(adj)**
POC	µg/L	579	795	492	n/a	log	0.668	0.623
PON	µg/L	49.9	59.8	57.4	n/a	log	0.987	0.510
F^-	mg/L	0.101	0.092	0.0856	0.1		7.33	6.09×10^{-3} *
Cl^-	mg/L	6.33	4.59	6.41	6.09	sqr	2.11	0.216
SO_4^{2-}	mg/L	13.9	16	26.9	44.6		7.09	6.44×10^{-3} *
Ca^{2+}	mg/L	19.7	42.7	35.6	36.3	sqr	27.4	1.02×10^{-6} *
K^+	mg/L	0.706	0.955	1.17	0.82		3.53	0.0787
Mg^{2+}	mg/L	12.4	11.8	9.33	10.1		4.19	0.0494 *
Na^+	mg/L	6.16	5.93	6.58	6.48		0.513	0.638
Si	mg/L	0.684	0.865	1.81	3.77	log	8.30	3.50×10^{-3} *
DOC	mg/L	12.5	9.43	10.8	6.29	log	0.881	0.534
DIC	mg/L	18.3	33.2	23.3	n/a		10.1	1.25×10^{-3} *
NH_4^+	µg/L	19	12.2	21.4	8.13	log	0.498	0.638
SRP	µg/L	0.508	0.41	0.733	n/a	log	2.13	0.216
ChlA	µg/L	1.14	0.92	1.42	1.73	log	0.606	0.629
Temp	deg C	15.7	15.9	17	17.7		1.09	0.488
Cond	uS/cm	179	258	236	275		14.4	1.09×10^{-4} *
DO	mg/L	13.6	12.8	10.4	9.24		5.23	0.0237 *
pH		9.52	8.35	8.38	8.01		19.9	1.44×10^{-5} *
NO_3^-/NO_2^-	µg/L	21.4	17.3	15.1	88.5	log	0.353	0.705
TKN	µg/L	550	456	352	320		17.0	3.22×10^{-5} *
DON	µg/L	481	384	273	253		18.7	1.82×10^{-5} *
TPP	µg/L	8.74	11	8.73	73.1	log	2.44	0.186
TDP	µg/L	15.2	17	13.5	5.52	log	1.11	0.488

Supplemental Table S2 – Trace metal mean values by closure type, with results of ANOVAs between closure types. Asterisks (*) denote variables with significant differences among closure types ($p < 0.05$).

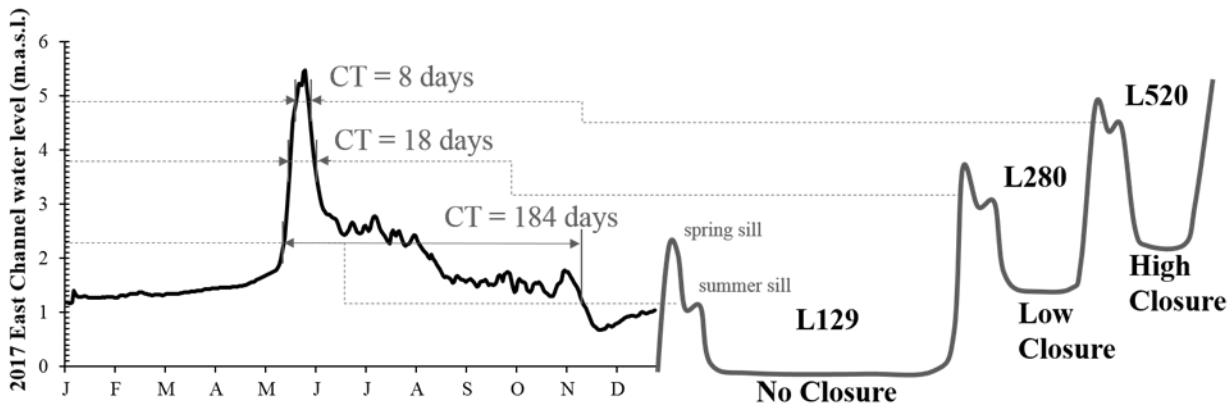
	Units	**High**	**Low**	**No**	**Transform**	***F***	***p*(adj)**
Ag	µg/L	0.0072	0.0067	0.00644	log	0.03	0.97
Al	µg/L	67.2	33	28.8	log	1.17	0.725
As	µg/L	0.975	0.984	1.06	log	0.72	0.733
B	µg/L	10.8	13.7	13.4		4.05	0.121
Ba	µg/L	82	126	79.3	log	7.77	0.0107 *
Be	µg/L	0.00464	0.0036	0.00489	log	0.199	0.862
Bi	µg/L	0.0032	0.0021	0.00389	log	0.651	0.733
Cd	µg/L	0.0316	0.0127	0.0168	log	1.18	0.725
Ce	µg/L	0.0836	0.0511	0.062	log	0.499	0.733
Co	µg/L	0.132	0.0828	0.0732	log	4.57	0.0902
Cr	µg/L	0.286	0.521	0.18	log	0.673	0.733
Cs	µg/L	0.0146	0.0107	0.00889	log	0.467	0.733
Cu	µg/L	1.44	0.968	1.85	sqr	2.6	0.337
Fe	µg/L	299	285	306	log	0.632	0.733
Ga	µg/L	0.0513	0.0415	0.0274	sqr	1.35	0.706
Ge	µg/L	0.0104	0.011	0.01	log	0.541	0.733
In	µg/L	0.004	0.0051	0.00578	log	0.282	0.842
La	µg/L	0.041	0.0265	0.0323	log	0.454	0.733
Li	µg/L	5.42	5.6	4.26		9.83	4.23×10^{-3} *
Mn	µg/L	13.7	13.1	12	log	0.61	0.733
Mo	µg/L	0.935	0.74	1.04		1.12	0.725
Nb	µg/L	0.00336	0.002	0.00256	log	0.719	0.733
Ni	µg/L	0.986	1.41	1.36	sqr	3.47	0.176
Pb	µg/L	0.129	0.0835	0.0923	log	1.48	0.706
Pt	µg/L	0.00516	0.0038	0.00678	sqr	0.632	0.733
Rb	µg/L	0.616	1.86	1.51	sqr	19.6	2.05×10^{-5} *
Sb	µg/L	0.0917	0.0758	0.0981		1.07	0.725
Sc	µg/L	0.026	0.04	0.03	log	0.7	0.733
Se	µg/L	0.125	0.117	0.21		8.46	8.18×10^{-3} *
Sn	µg/L	0.0511	0.054	0.0358	sqr	0.692	0.733
Sr	µg/L	146	230	195		33.3	9.97×10^{-8} *
Ti	µg/L	0.986	0.7	0.489	log	0.53	0.733
Tl	µg/L	0.0022	0.0021	0.00389	sqr	2.17	0.422
U	µg/L	0.218	0.258	0.412		5.85	0.0377 *
V	µg/L	0.433	0.28	0.273		1.4	0.706
W	µg/L	0.00452	0.0025	0.00567	sqr	2.15	0.422
Y	µg/L	0.0523	0.0425	0.056	log	0.195	0.862
Zn	µg/L	3.5	2.56	3.49	log	0.452	0.733
Zr	µg/L	1.11	1.15	1.2	sqr	0.175	0.862

Supplemental Table S3 – Composition of trace metals in lakes, with comparison with main channel.

Asterisks (*) denote variables with significant differences between the lakes and the channel ($p < 0.05$).

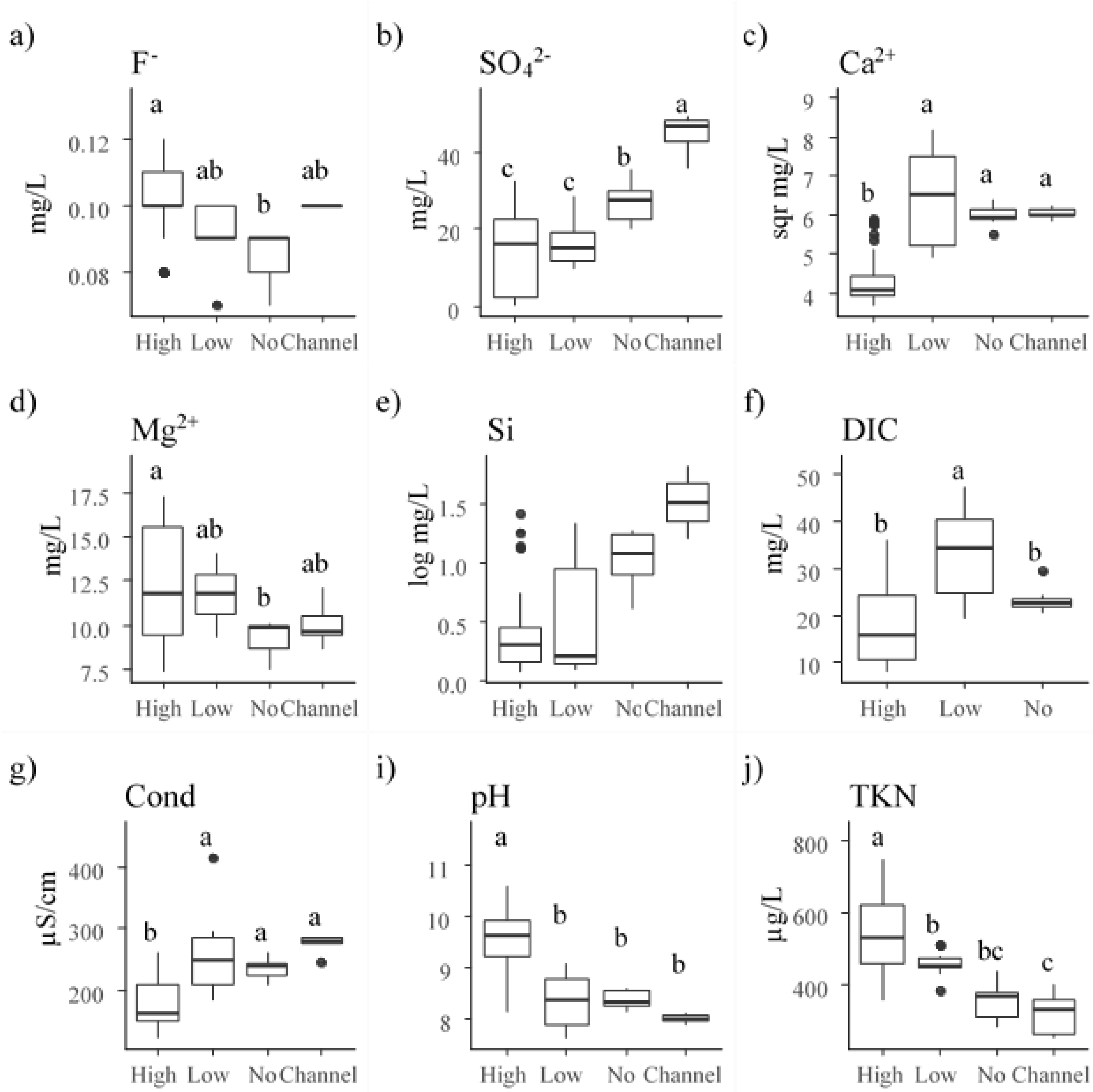
	Lakes (µg/L)	**% of total lake TM**	**Channel (µg/L)**	***p*(adj)**	**Channel:Lake**
Ag	0.00693	0.00105	0.12	2.99×10^{-20} *	17.3
Al	51.6	7.83	2280	1.08×10^{-9} *	44.2
As	0.995	0.151	1.55	0.00026 *	1.55
B	12	1.82	n/a	n/a	n/a
Ba	91.4	13.9	103	0.298	1.13
Be	0.00445	0.000677	0.14	8.69×10^{-22} *	31.4
Bi	0.00308	0.000468	n/a	n/a	n/a
Cd	0.0242	0.00368	0.12	2.2×10^{-6} *	4.95
Ce	0.0661	0.01	n/a	n/a	n/a
Co	0.109	0.0165	1.33	1.02×10^{-16} *	12.3
Cr	0.318	0.0482	3.34	1.87×10^{-11} *	10.5
Cs	0.0126	0.00191	0.48	4.99×10^{-21} *	38.2
Cu	1.42	0.216	4.07	3.7×10^{-6} *	2.87
Fe	297	45.1	3190	5.72×10^{-12} *	10.7
Ga	0.187	0.0284	n/a	n/a	n/a
Ge	0.0104	0.00158	n/a	n/a	n/a
In	0.00458	0.000696	n/a	n/a	n/a
La	0.0345	0.00524	n/a	n/a	n/a
Li	5.22	0.793	7.4	2.79×10^{-5} *	1.42
Mn	13.2	2.01	55.8	2.2×10^{-6} *	4.21
Mo	0.911	0.138	1.23	0.134	1.35
Nb	0.00288	0.000437	n/a	n/a	n/a
Ni	1.16	0.176	5.26	3.12×10^{-11} *	4.54
Pb	0.111	0.0169	1.79	1.15×10^{-21} *	16.1
Pt	0.0651	0.00988	n/a	n/a	n/a
Rb	1.08	0.165	5.39	1.86×10^{-8} *	4.98
Sb	0.0894	0.0136	0.2	1.79×10^{-8} *	2.24
Sc	0.0291	0.00443	n/a	n/a	n/a
Se	0.14	0.0213	0.58	1.46×10^{-14} *	4.13
Sn	0.207	0.0314	n/a	n/a	n/a
Sr	175	26.6	209	0.134	1.19
Ti	0.819	0.124	44.9	7.19×10^{-13} *	54.8
Tl	0.00252	0.000383	n/a	n/a	n/a
U	0.267	0.0406	0.86	7.83×10^{-10} *	3.22
V	0.366	0.0555	6.05	7.86×10^{-16} *	16.6
W	0.0603	0.00916	n/a	n/a	n/a
Y	0.0484	0.00735	n/a	n/a	n/a
Zn	3.28	0.498	15.6	1.02×10^{-6} *	4.75
Zr	0.962	0.146	n/a	n/a	n/a

Supplemental Fig. S1



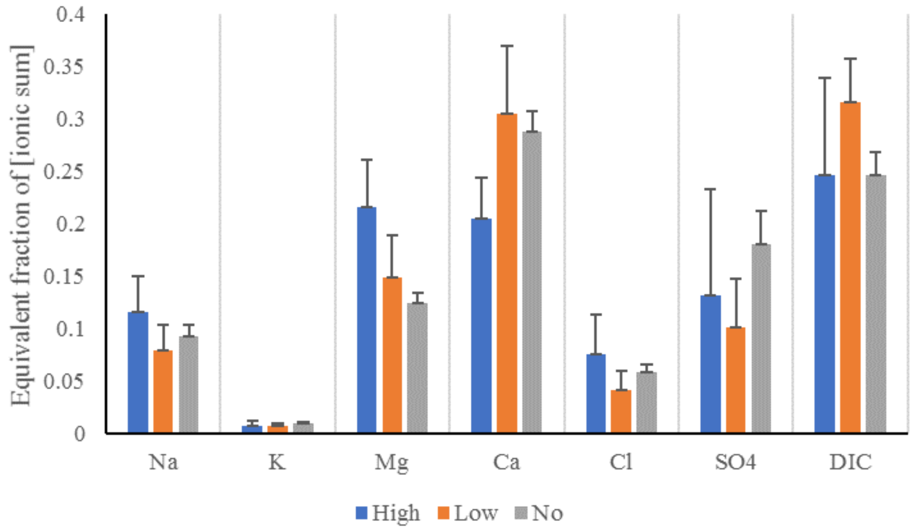
Supplemental Fig. S1 – Lake connection time in representative lakes for the three lake closure types in 2017. The hydrograph depicts daily maximum water level measured by an ECCC hydrometric monitoring station in the East Channel at Inuvik. Lake sill elevations were obtained from Marsh and Hey (1988). Due to snow and ice accumulation over the winter that persists into the spring flooding period, spring sills are higher than summer sills; spring sill elevations are used for CT calculations up until the date of the first post-peak rise in water levels, and summer sill elevations used after this date. Lake basins are drawn to scale based on sill elevations, average depth, and maximum width, but do not portray basin morphometry. Lake 129 is directly connected to the East Channel by a distributary channel, so the summer sill value represents the elevation of the thalweg of the distributary channel rather than the elevation at which overbank flooding occurs.

Supplemental Fig. S2



Supplemental Fig. S2 – Boxplots of ions and nutrients with significant differences among closure types and the main channel. Plots display the median (horizontal line), first and third quartiles (lower and upper hinges), smallest and largest values no further than 1.5 x the interquartile range from the lower or upper hinge (whiskers), and outliers (dots). Significantly different pairwise tests are indicated by different letters.HC lakes were characterized by high pH and nitrogen (primarily as DON) and low Ca^{2+}, Si and specific conductivity, and LC lakes by high DIC. Concentrations of most water quality parameters were similar in the NC lakes and the main channel. Chemical parameters in the channel showed lower variation across years than those in the lakes and differed significantly from the HC lakes but not the LC or NC lakes.

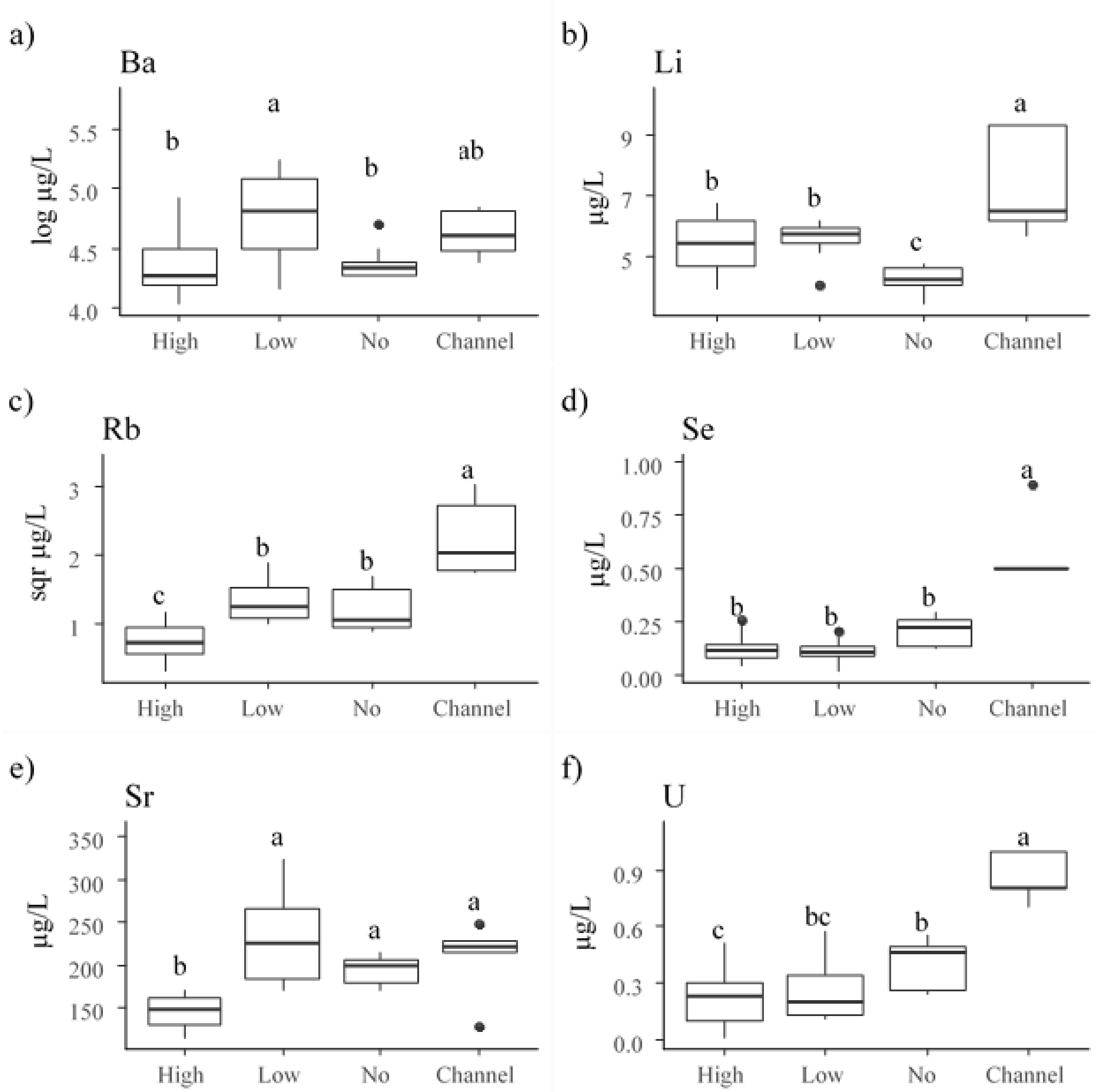
Supplemental Fig. S3



Supplemental Fig. S3 – Major ion composition of lakes by closure type. Mean concentrations of major ions represented as fractions of ionic sum. Error bars are one standard deviation. The composition of major ions, represented by fractions of the sum of ionic constituents, varied among the closure types. DIC was the dominant anion in all lake types, with high concentrations of SO_4^{2-} in NC lakes equivalent to ~ half of the SO_4^{2-} in the channel (Supplemental Table S1). Dominant cations in the lake types were Mg^{2+} in HC lakes and Ca^{2+} in LC and NC lakes. Of the major ions Mg^{2+} had the clearest relationship to connection time, decreasing among the closure types from highest elevation to lowest.

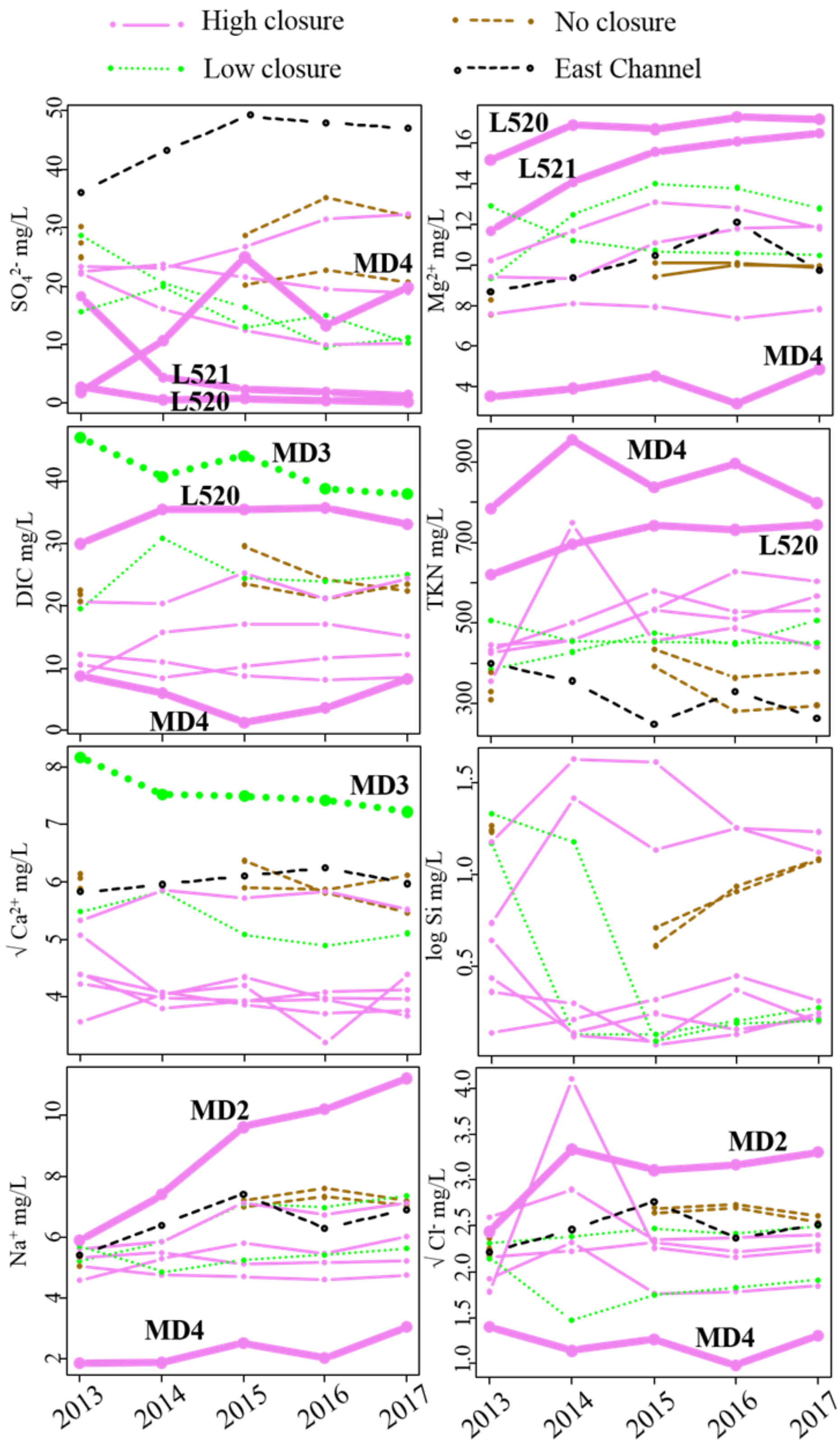
Lesack et al. (1998) conducted a major survey of major ions in Mackenzie Delta lakes, identifying three end members of ionic composition: 1) Ca^{2+} + HCO_3^- corresponding to lakes with frequent and sustained connection to the river, 2) Mg^{2+} + HCO_3^- corresponding to lakes that are flooded infrequently for short periods, and 3) Ca^{2+} + SO_4^{2-} corresponding to lakes with sufficiently high sill elevation to prevent inundation during spring flooding for multiple consecutive years. Although our study differs in design and methodology, our results are consistent with the framework they proposed. Dominant cation/anion pairs in High closure lakes corresponded to end member 2 (Mg^{2+} + HCO_3^-) and Low closure and No closure lakes to end member 1 (Ca_{2+} + HCO_3^-). Although the fraction of Ca^{2+} in High closure lakes was nearly as high as that of the dominant cation Mg^{2+}, the absolute concentration of Ca^{2+} was considerably lower in the High closure lakes than the other groups. Evidence for end member 3 (Ca^{2+} + SO_4^{2-}), which comprised a small set of very high elevation lakes in Lesack et al. (1998), is equivocal: thermokarst lake L520 had high Ca^{2+} relative to other High closure lakes, and MD4 had high SO_4^{2-} following drainage (Supplemental Fig. S5), but no lake was dominated by the pair of Ca^{2+} + SO_4^{2-}. Overall, our results fit within the interpretive framework of Lesack et al. (1998) and subsequent studies. Using a gradient-based PCA approach we found that variation in limnological condition among lakes and years was concentrated along two interpretable axes which were both significantly associated with connection time.

Supplemental Fig. S4



Supplemental Fig. S4 – Boxplots of trace metals with significant differences among closure types and the main channel. Plots display the median (horizontal line), first and third quartiles (lower and upper hinges), smallest and largest values no further than 1.5 x the interquartile range from the lower or upper hinge (whiskers), and outliers (dots). Significantly different pairwise tests are indicated by different letters.

Supplemental Fig. S5



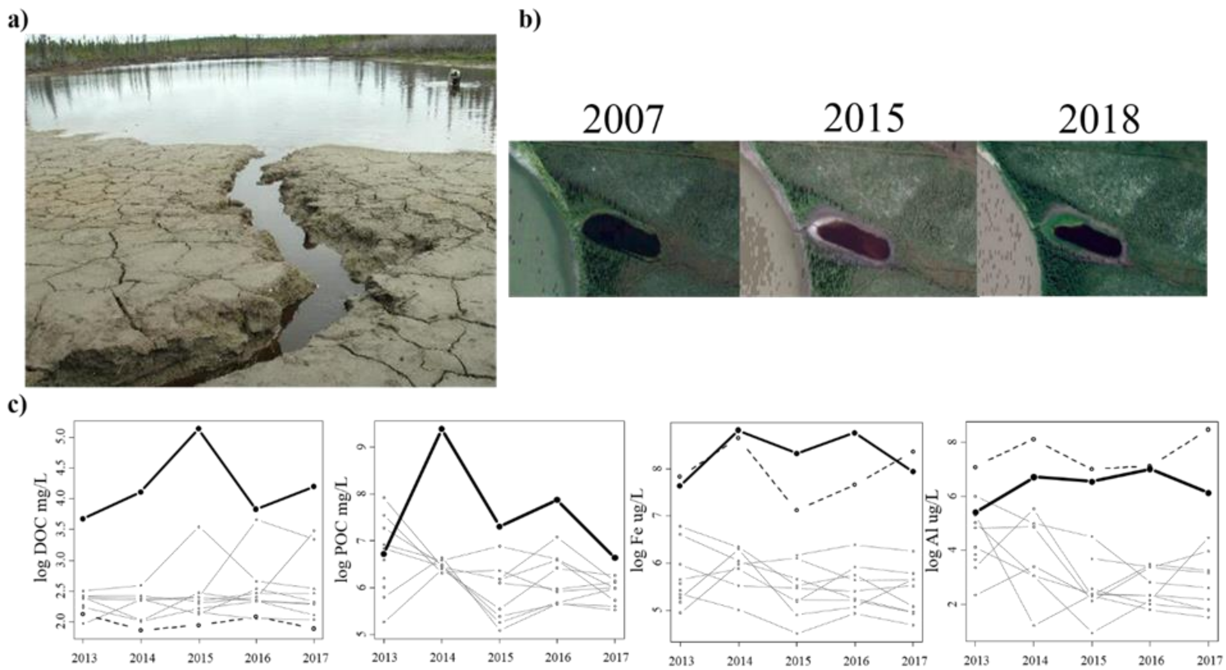
Supplemental Fig. S5 – Water chemistry parameters over the sampling period for eight important variables in each study lake. Channel concentrations are shown by a dotted line when available. Lakes discussed in the text are highlighted and labelled. Temporal changes of the significant parameters from the ANOVA and PCA analyses differed among lake closure types and in some cases individual lakes. NC lakes were similar to the channel for each variable with the exception of SO_4^{2-}, which was considerably higher in the channel than in any lake. Variables with high loadings on PC2 reflected closure type most strongly and were relatively stable over time. SO_4^{2-} was higher on average in the NC lakes than the HC lakes, with lowest concentrations in the thermokarst L520, and declined over the study period in the LC lakes. Mg^{2+} in the HC lakes was quite variable but most concentrated in the highest elevation HC lakes (L520 and L521). TKN was not distinct among closure types in the high flood year 2013 but became increasingly so over time due to increases in the HC lakes.

Of the variables that contributed to PC1, DIC and Ca^{2+} also reflected closure type. HC lakes had lower DIC and Ca^{2+} than the closure types with longer connection times to the main channels. An exception was thermokarst lake L520 with high concentrations of DIC, Ca^{2+} and Si that increased over time. In LC lakes DIC and Ca^{2+} declined over the study period, with higher concentrations and more prominent declines in lake MD3. Si was high in both LC lakes in 2013 but declined in subsequent years, with precipitous drops occurring in 2013 (L280) and 2015 (MD3).

While there was little overall difference in Na^+ between closure types or years, individual lakes had temporal trends worth noting because they potentially reflect water source. NC lakes had similar Na^+ to the main channel with isolated (HC and LC) lakes having slightly lower concentrations. Uniquely, Na^+ increased steadily over the study period in lake MD2, nearly doubling in concentration between 2013 and 2017. Cl^- also increased in MD2 over the study period, but most of the increase occurred between 2013 and 2014 and was subsequently stable.

The drained lake MD4 had anomalous values and/or trends for each of these variables other than Ca^{2+}. SO_4^{2-} was lowest in the high-flood year 2013 and increased after the lake drained, stabilizing by 2017 at ~ 20x the 2013 concentration. Dissolved ions (Mg^{2+}, DIC, Na^+ and Cl^-) were extremely low in all years of the study. TKN and Si increased following the drainage event in 2014, similar to the trends in DOC, particulates, and trace metals (Supplemental Fig. S6).

Supplemental Fig. S6



Supplemental Fig. S6 – Physical and chemical changes in lake MD4. a) Bank of MD4 in 2014 (post-drainage) showing previously submerged substrate and small outflow channel. b) Historical satellite images of MD4 (obtained from Google Earth) showing changes to the shoreline and basin. In 2007 the lake basin was full, as it was in 2013 (the first year of the sampling period). After the drainage event that occurred between the 2013 and 2014 sampling seasons water had visibly receded and barren shoreline is visible. By 2018 vegetational succession along lake margins is apparent. c) Elevated levels of DOC, POC and two representative trace metals in MD4 (bold solid line). Channel data is represented by a dashed line when available.

In our statistical analyses, we excluded this unnamed high closure lake (provisionally called MD4) that partially drained between the sampling seasons of 2013 and 2014. In 2013 the lake was > 1 m deep in the nearshore region, but in subsequent years water levels were reduced to < 0.5 m in the centre of the basin and previously submerged sediment around the edges of the lake were now exposed mud flats (Supplemental Fig. S6a). Historical satellite imagery shows that this lake was full throughout the decade prior to the sampling period, and visibly contracted in 2014 and thereafter, with successional vegetation in the exposed former lake bed occurring from 2015 onwards (Supplemental Fig. S6b). This alteration of the lake had strong effects on observed water chemistry, with highly elevated particulates and trace metals post-alteration (Supplemental Fig. S6c). While the extreme values of water chemistry components dominated variation in statistical analyses of the full lake set and required removal of MD4 as an ‘outlier’ (to discern inter-lake variation within the rest of the dataset), we include MD4 in subsequent discussion of temporal variation, as it may represent a limnological future of extended lake isolation and subsequent lake level drawdown in a warmer climate.