

Supplemental Information For:

Exploring the Influence of Industrial and Climatic Variables on Communities of Benthic Macroinvertebrates Collected in Streams and Lakes in Canada's Oil Sands Region

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Supplemental Tables

Supplemental Table S1 Cumulative land disturbances (%) for stream sites; calculated from ABMI 2018; STR=Steepbank River; JP=Jackpine Creek; MUR=Muskeg River; FB=Firebag River; ELR=Ells River; MAC=MacKay River; SHP=Shipyards Lake; ISL=Isadore's Lake; MCL=McClelland Lake; L=Lower; U=Upper; M=Middle; locations and watersheds shown in Figure 1; proportion of land disturbance (ALD) calculated as difference per year.

Year	ELR		FB		JP		MAC		MUR			STR	
	L	U	L	U	L	U	L	M	L	M	U	L	U
2000	0.341	0.359	0.055	0.074	0.784	0.343	0.556	0.552	2.676	2.780	0.693	0.290	0.007
2001	0.428	0.419	0.146	0.207	0.933	0.384	0.665	0.623	5.168	5.241	0.925	0.429	0.076
2002	0.453	0.430	0.153	0.219	1.579	1.300	0.701	0.637	6.142	6.271	1.047	0.560	0.077
2003	0.491	0.446	0.236	0.348	1.723	1.506	0.717	0.649	6.394	6.533	1.442	0.652	0.136
2004	0.550	0.479	0.377	0.392	1.937	1.597	0.793	0.718	6.967	7.138	1.638	0.755	0.223
2005	0.616	0.512	0.465	0.559	2.007	1.772	0.823	0.747	7.620	7.762	2.282	0.912	0.242
2006	0.649	0.523	0.520	0.642	2.660	1.803	0.848	0.755	8.918	9.108	2.670	1.141	0.308
2007	0.710	0.558	0.676	0.663	3.925	1.806	0.896	0.798	10.825	10.863	3.069	1.665	0.340
2008	0.784	0.603	0.766	0.718	4.254	1.808	1.025	0.893	11.496	11.569	3.361	2.840	0.440
2009	0.856	0.644	1.158	0.730	4.915	2.533	1.147	0.982	12.183	12.285	4.314	3.064	0.449
2010	0.878	0.669	1.254	0.762	5.307	2.554	1.214	1.035	13.323	13.479	4.939	3.775	0.449
2011	0.884	0.672	1.421	0.829	5.387	2.590	1.308	1.087	14.476	14.578	5.521	4.006	0.479
2012	1.370	0.757	1.566	0.897	5.449	2.598	1.477	1.178	15.949	16.128	6.495	4.236	0.498
2013	1.541	0.764	1.800	0.952	5.486	2.634	1.561	1.233	16.567	16.736	7.911	4.422	0.501
2014	1.603	0.765	1.896	0.979	5.499	2.642	1.595	1.270	17.219	17.425	9.673	4.642	0.502
2015	1.606	0.768	1.920	1.045	5.529	2.690	1.607	1.282	17.479	17.696	10.259	4.693	0.519

Supplemental Table S2 Cumulative land disturbance (%) for the four study lakes per study year; proportion of land disturbance (ALD) calculated as difference per year; locations and watersheds shown in Figure 1.

Year	Lake			
	Isadore's	Kearl	McClelland	Shipyard
2000	11.47	1.49	0.12	8.52
2001	23.47	1.90	0.29	10.53
2002	26.02	1.91	0.30	16.03
2003	27.15	2.43	0.48	16.04
2004	29.76	2.51	4.11	29.70
2005	29.78	2.77	4.11	45.87
2006	29.78	3.08	4.12	66.38
2007	30.14	3.08	7.77	75.01
2008	32.03	3.09	8.56	84.58
2009	32.03	4.07	8.76	84.59
2010	32.10	4.50	8.83	84.63
2011	38.73	4.64	9.36	84.63
2012	40.01	8.07	9.36	84.63
2013	43.54	8.27	9.66	85.23
2014	43.96	8.42	9.96	85.23
2015	44.61	8.42	9.96	85.23

Supplemental Table S3 Selection rates, ranks, counts per BMI index, and number of sites with a selected variable of industrial and climatic variables returned by EN using a lower limit of zero (0) for industrial variables and no constraints for MSP, MST, and MSWS; TA=total abundance; TR=taxon richness; EPT=percent EPT; EQ=equitability; NA=not applicable; 19 models were intercept only; variable codes defined in main article body (See Section 2.2)

Feature	Models with feature	Feature selection rate (%)	Selection rank for industrial features	Selection rank among all features
MST	19	27.94	NA	1
MSWS	19	27.94	NA	1
MSP	14	20.59	NA	3
SML-FPU	14	20.59	1	3
JPM-CBP	13	19.12	2	5
CLD	11	16.18	3	6
KM-CBP	11	16.18	3	6
SBM-FPU	11	16.18	3	6
HM-PCP	10	14.71	6	9
SBM-SCP	9	13.24	7	10
SML-CBP	9	13.24	7	10
SML-PCP	9	13.24	7	10
HM-PCS	8	11.76	10	13
SAN-CBP	8	11.76	10	13
SML-SCP	8	11.76	10	13
HM-CBP	7	10.29	13	16
HM-SCP	7	10.29	13	16
SBM-PCP	7	10.29	13	16
ALD	6	8.82	16	19
MRM-CBP	6	8.82	16	19
SBM-CBP	6	8.82	16	19
SFB-B	6	8.82	16	19
SML-PCS	6	8.82	16	19
SMR-B	5	7.35	21	24
SBMPCS	5	7.35	21	24
SMR-ST	4	5.88	23	26
SFB-ST	2	2.94	24	27

Supplemental Table S4 Selection rates, ranks, counts per BMI index, and number of sites with a selected variable of in-dustrial and climatic variables returned by EN with no constraints for any variables MSP, MST, and MSWS; TA=total abundance; TR=taxon richness; EPT=percent EPT; EQ=equitability; NA=not ap-plicable; 15 models were intercept only; variable codes defined in main article body (See Section 2.2).

Feature	Feature selection count	Proportional selection rate (%)	Rank of all β for industrial features	Positive (+) β coefficients	Negative (-) β coefficients	Rank of + β for industrial features	Rank of - β for industrial features	Rank of + β for all features	Rank of - β for all features
JPM-CBP	17	25.00	1	12	5	1	5	1	8
SML-FPU	17	25.00	1	12	5	1	5	1	8
MST	16	23.53	NA	6	10	NA	NA	15	1
SBM-FPU	16	23.53	3	6	10	15	1	15	1
HM-PCP	15	22.06	4	10	5	4	5	4	8
KM-CBP	15	22.06	4	9	6	5	3	5	6
MSWS	14	20.59	NA	5	9	NA	NA	19	3
HM-CBP	14	20.59	6	9	5	5	5	5	8
HM-SCP	14	20.59	6	9	5	5	5	5	8
MRM-CBP	13	19.12	8	5	8	18	2	19	4
SAN-CBP	13	19.12	8	8	5	9	5	9	8
SBM-CBP	13	19.12	8	8	5	9	5	9	8
SBM-SCP	12	17.65	11	9	3	5	16	5	19
SML-PCP	12	17.65	11	8	4	9	13	9	16
SML-SCP	12	17.65	11	11	1	3	20	3	23
MSP	11	16.18	NA	4	7	NA	NA	23	5
HM-PCS	11	16.18	14	8	3	9	16	9	19
SBM-PCP	11	16.18	14	7	4	14	13	14	16
SML-CBP	11	16.18	14	5	6	18	3	19	6
SMR-ST	10	14.71	17	6	4	15	13	15	16
CLD	9	13.24	18	8	1	9	20	9	23
ALD	9	13.24	18	4	5	21	5	23	8
SMR-B	9	13.24	18	6	3	15	16	15	19
SBM-PCS	6	8.82	21	4	2	21	19	23	22
SML-PCS	6	8.82	21	5	1	18	20	19	23
SFB-B	4	5.88	23	4	0	21	23	23	26
SFB-ST	3	4.41	24	3	0	24	23	27	26

Supplemental Table S5 Results of Elastic Net variable selection for additional sites east of the Athabasca River; variable codes defined in main article body (See Section 2.2); Locations shown in Figure 1; TA=total abundance; TR=taxon richness; EPT=percent EPT; EQ=equitability).

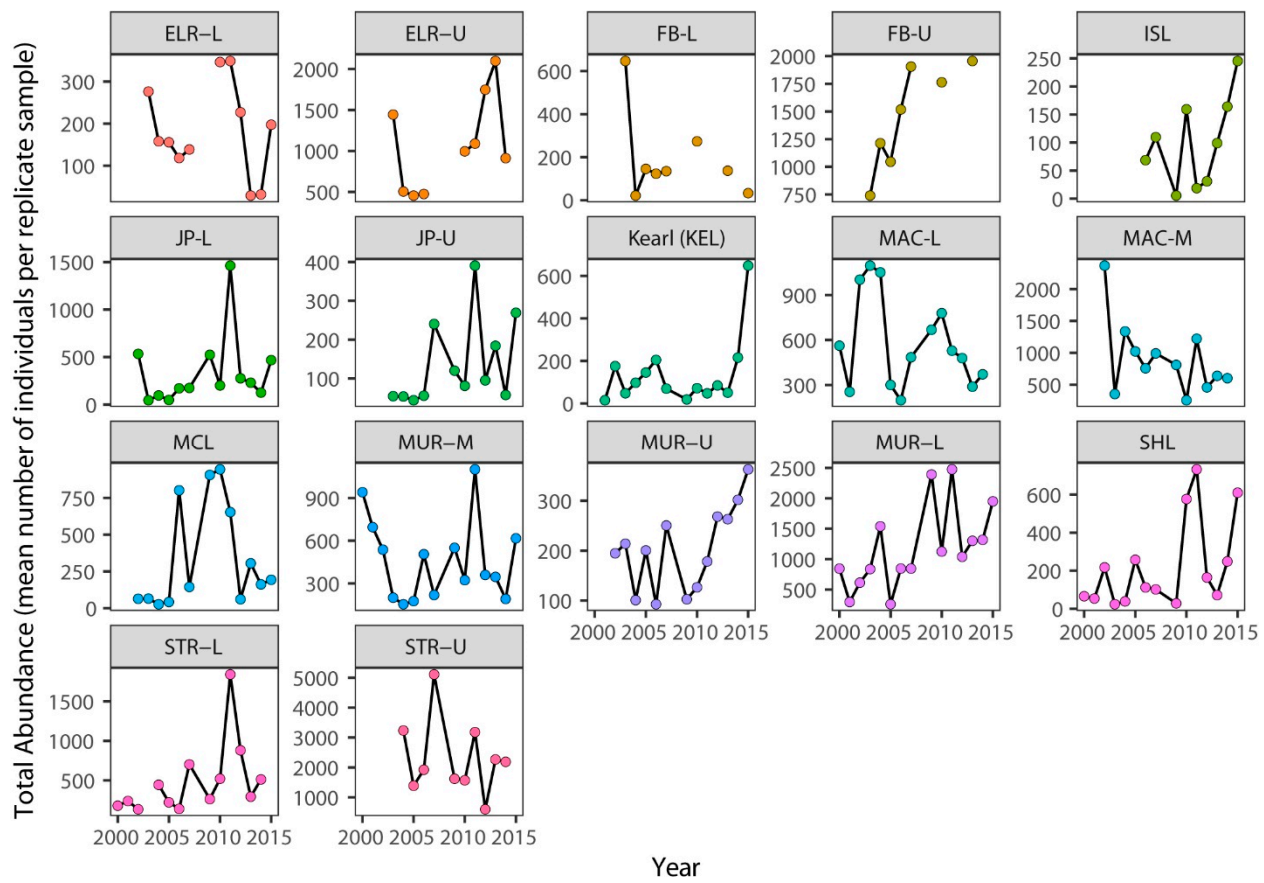
BMII	Feature	Firebag		Muskeg River			Lakes		
		FB-L	FB-U	MUR-L	MUR-M	MUR-U	ISL	KEL	MCL
TA	DR	0	0.95	0.70	0.59	0.19	0.23	8.0×10^{-17}	0.36
	Intercept	3.1×10^{-16}	2.4×10^{-16}	-2.5×10^{-16}	-5.9×10^{-16}	-1.2×10^{-15}	-6.8×10^{-16}	1.1×10^{-16}	6.2×10^{-16}
	ALD		-0.419	-0.376					
	MSWS		0.025	0.096	0.050	-0.186	-0.184		
	MST				0.404				0.341
	MRM-CBP				-0.321				
	MSP			-0.501	-0.121				
	SAN-CBP				-0.346				
	SBM-FPU		-0.572	-0.278					-0.041
	SMR-ST				-0.014				
EPT	SML-CBP		-0.068					-7.1×10^{-17}	
	DR	0.000	>0.99	0.00	0.26	0.00	0.899	0.00	0.56
	Intercept	-4.2×10^{-17}	-2.7×10^{-15}	2.4×10^{-16}	3.7×10^{-16}	9.0×10^{-17}	-6.1×10^{-16}	5.6×10^{-17}	-1.1×10^{-15}
	MSWS						-0.416		-0.093
	MST				0.002		-0.054		-0.079
	MSP		0.062						0.019
	SBM-CBP		-0.102						
	SBM-FPU				-0.140		-0.260		-0.405
	SBM-PCS		-0.196						
	SBM-PCP		-0.275						
	SBM-SCP		-0.351						
	SML-CBP		-0.079		-0.176				
	SML-FPU		-0.084				-0.068		-0.084
	SML-PCP		-0.078				-0.069		-0.085
	SML-PCS		-0.073						
EQ	SML-SCP		-0.057						
	DR	0.58	0.19	0.17	0.00	0.55	0.44	0.00	0.07
	Intercept	8.8×10^{-16}	1.0×10^{-16}	1.6×10^{-16}	1.9×10^{-16}	-3.6×10^{-16}	3.5×10^{-16}	-6.2×10^{-17}	-2.3×10^{-16}
	CLD		-0.013						
	ALD					-0.009			
	HM-CBP			-0.058					
	HM-PCP			-0.020					
	HM-PCS			-0.082					
	HM-SCP			-0.058					
	MSWS						0.266		
	JPM-CBP		-0.010			-0.005			
	KM-CBP	-0.042		-0.006		-0.518			
	MST	-0.351							-0.046
	MSP	-0.045				-0.090			
	SBM-CBP	-0.111							
	SMR-ST						-0.165		
	SBM-PCS		-0.033						
	SBM-PCP	-0.037							-0.015
	SML-CBP	-0.285				-0.172			
TR	SML-PCS		-0.057						
	DR	0	0.20	0.38	0.81	0.16	0.78	0.41	0.15
	Intercept	-1.1×10^{-16}	2.7×10^{-15}	1.9×10^{-15}	-4.5×10^{-16}	-3.3×10^{-16}	-1.7×10^{-15}	3.8×10^{-16}	3.8×10^{-16}
	ALD		-0.115		-0.103				
	HM-CBP						-0.041		
	HM-PCP						-0.088		
	HM-SCP						-0.046		
	MSWS			0.365		-0.158	-0.543	-0.131	
	MST				0.550				0.114
	MRM-CBP				-0.671				
	MSP			-0.192	-0.102				
	SAN-CBP				-0.233				
	SBM-CBP				-0.146				
	SBM-FPU		-0.075	-0.019	-0.704			-0.187	
	SML-CBP							-0.029	
	SML-FPU						-0.077	-0.079	
	SML-PCP						-0.077		

Supplemental Table S6 Results of Elastic Net variable selection for additional sites east of the Athabasca River; variable codes defined in main article body (See Section 2.2); Locations shown in Figure 1; TA=total abundance; TR=taxon richness; EPT=percent EPT; EQ=equitability).

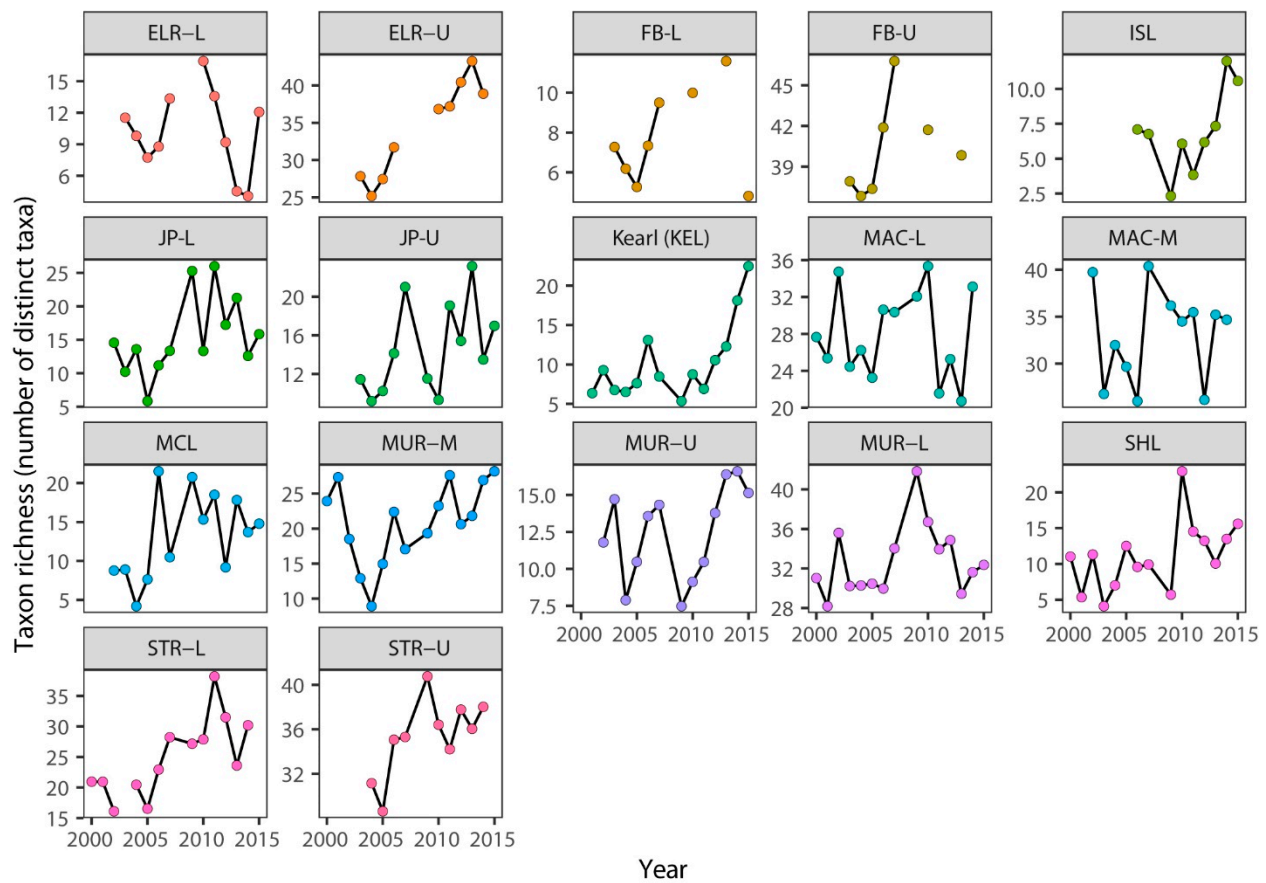
BMII	Feature	Ells		MacKay	
		ELR-L	ELR-U	MAC-L	MAC-M
TA	DR	0	0.36	0.57	0.93
	Intercept	-9.02×10^{-17}	-2.85×10^{-15}	-9.85×10^{-16}	-5.12×10^{-15}

	HM-CBP				-0.018
	HM-SCP				-0.017
	MSWS		-0.069	0.418	0.992
	MST			-0.602	-0.650
	MRM-CBP		-0.265		-0.115
	MSP			-0.558	-0.379
	SFB-B			-0.189	
	SBM-FPU				-0.442
	SMR-B				-0.037
	SMR-ST				-0.105
	SML-CBP				-0.439
	SML-FPU			-0.133	-0.265
	SML-PCP				-0.265
EPT	DR	0	0.10	0	0.67
	Intercept	-8.33×10^{-17}	2.92×10^{-16}	1.80×10^{-16}	2.44×10^{-16}
	MSWS				-0.259
	JPM-CBP				-0.047
	MSP		-0.073		-0.113
	SBM-FPU		-0.037		-0.576
EQ	DR	0	0.23	<0.01	0.51
	Intercept	2.48×10^{-16}	-4.28×10^{-16}	2.84×10^{-16}	1.31×10^{-15}
	WS				-0.961
	KM-CBP				-0.734
	MST		-0.160		-0.119
	MSP				-0.021
	SBM-CBP			-3.79×10^{-17}	
TR	DR	0.26	0.88	0	3.1×10^{-17}
	Intercept	2.81×10^{-16}	-9.95×10^{-16}	1.39×10^{-17}	-7.77×10^{-16}
	MSWS	0.113			
	KM-CBP	-0.135			
	MRM-CBP		-0.279		-4×10^{-17}
	MSP	-0.032	-0.057		
	SBM-CBP		-0.023		
	SBM-FPU		-0.812		

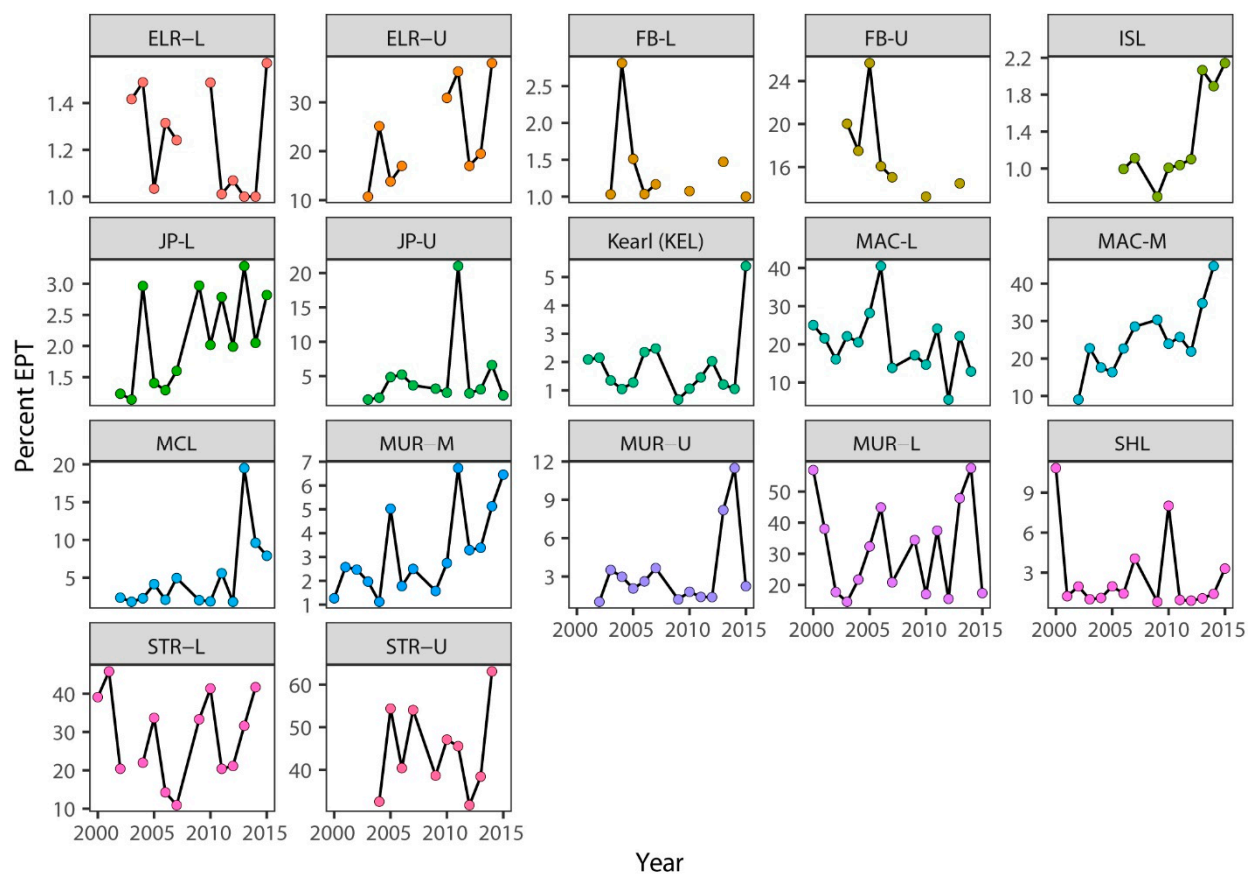
Supplemental Figures



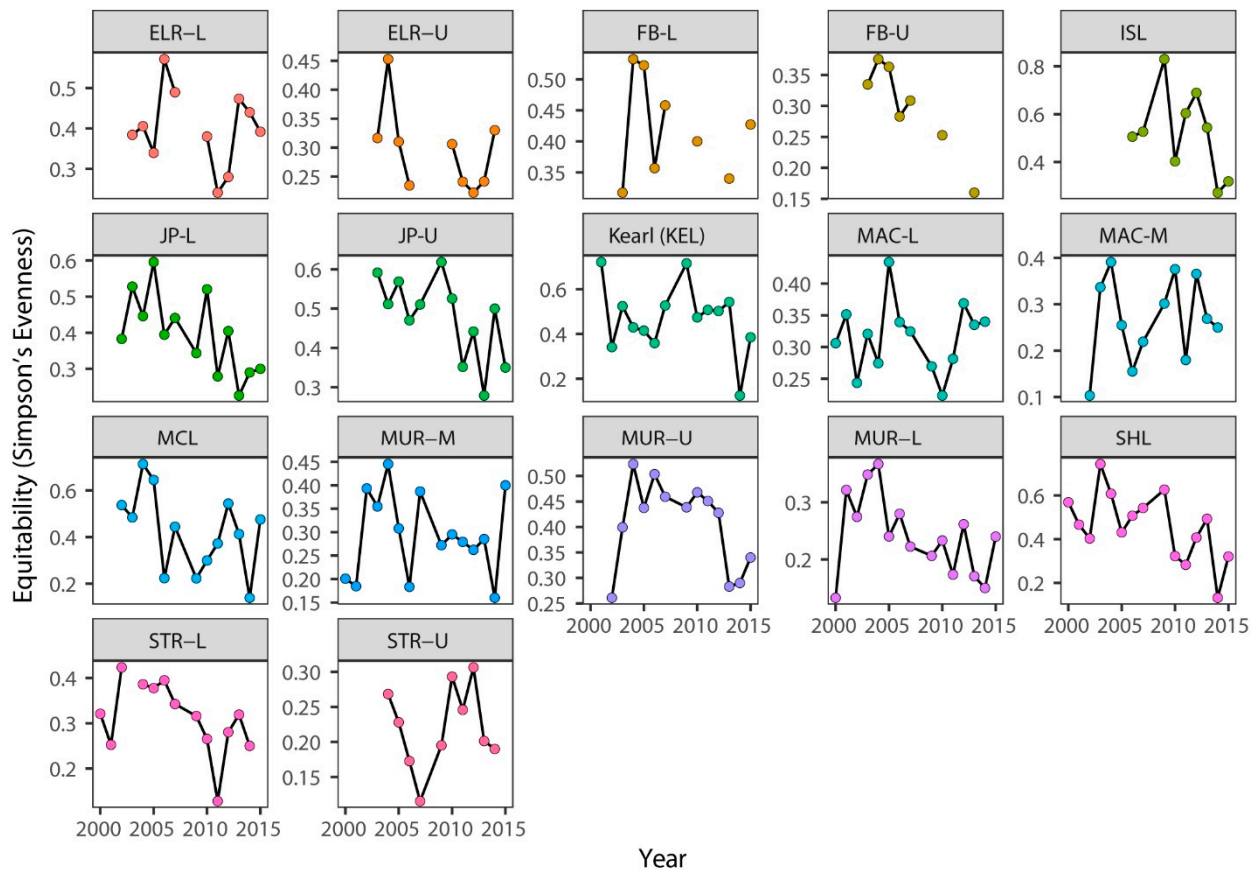
Supplemental Figure S1 Total abundance of benthic macroinvertebrates from RAMP.



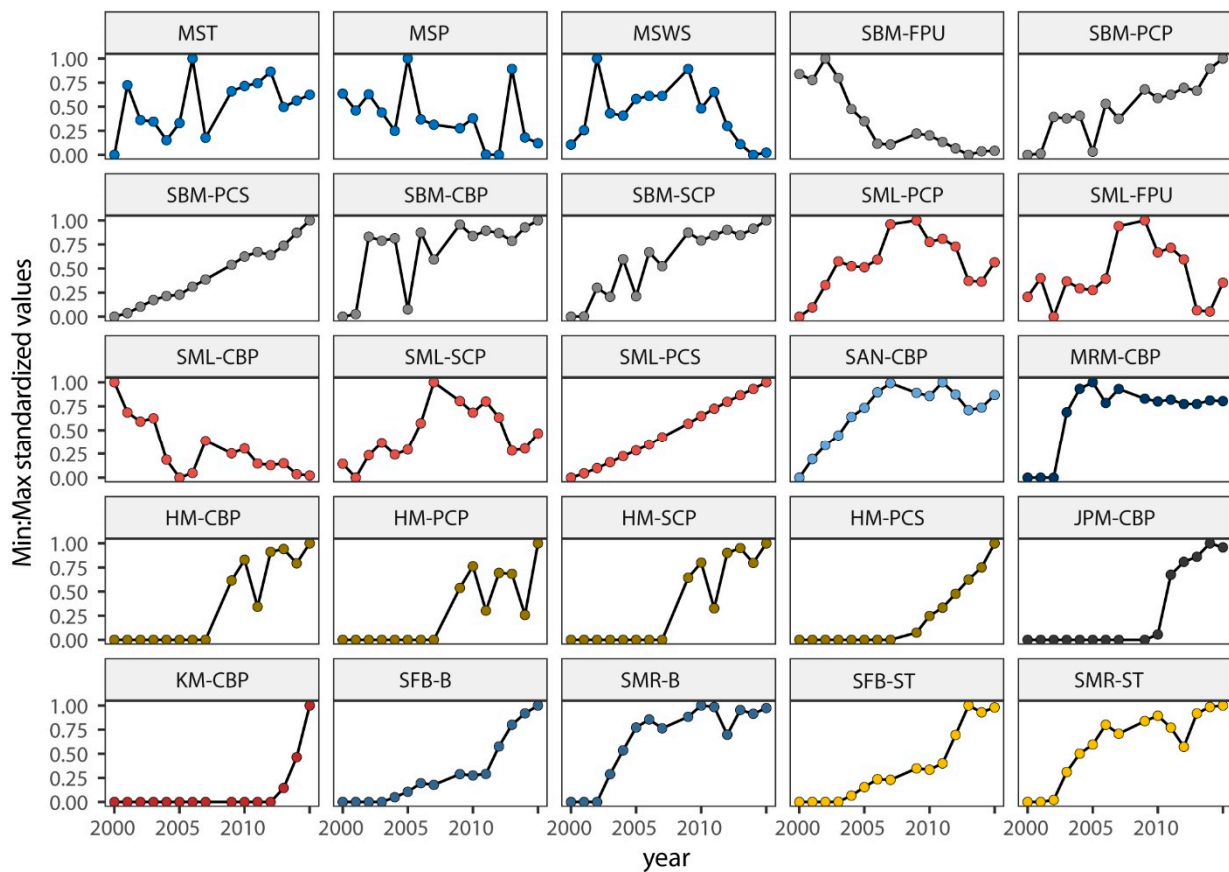
Supplemental Figure S2 Taxon richness of benthic macroinvertebrates from RAMP.



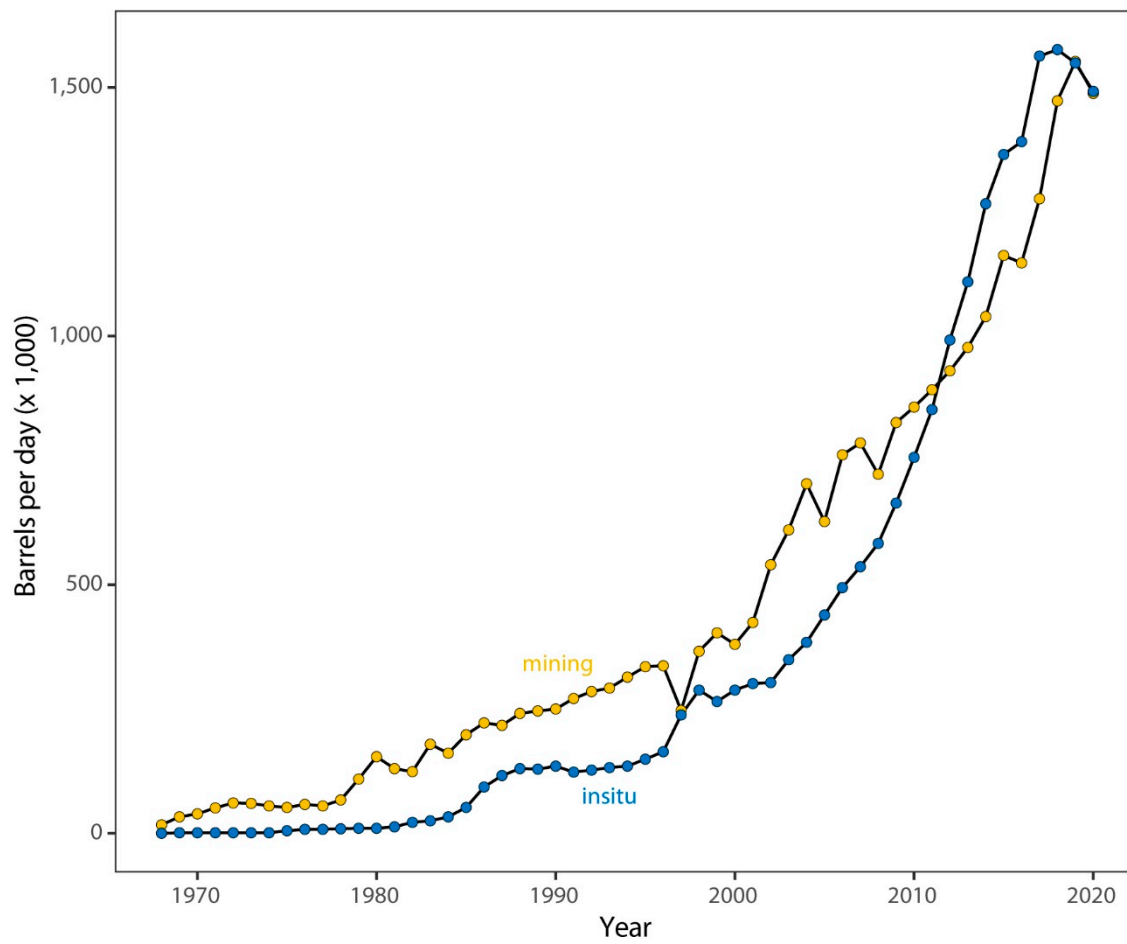
Supplemental Figure S3 Percent EPT of benthic macroinvertebrates data from RAMP.



Supplemental Figure S4 Equitability of benthic macroinvertebrates from RAMP.



Supplemental Figure S5 Selectable industry (and 'climatic'[MSP, MST, MSWS]) variables obtained for EN; values standardized to minimum and maximum values per variable (minimum=0; maximum=1); MST = mean summer temperature; MSP = mean summer precipitation; MSWS = mean summer wind speed; Suncor Basemine =SBM, Syncrude Mildred Lake = SML, Horizon Mine = HM, Syncrude Aurora North = SAN, Muskeg River Mine = MRM, Jackpine Mine = JPM, Kearl Mine = KM, Suncor Firebag in situ = SFB, and Suncor MacKay River in situ = SMR; fuel/plant use of petroleum coke =FPU, petroleum coke production = PCP, closing inventory of petcoke stockpiles = PCS, crude bitumen production = CBP, synthetic crude production = SCP ; bitumen production = B; steam injection = ST.



Supplemental Figure S6 Mining and in situ production (thousands of barrels per day) over time; data obtained from www.oilsandsmagazine.com [accessed on 5 October 2021].