

Supplemental information for:

Incorporating Industrial and Climatic Covariates into Analyses of Fish Health Indicators Measured in a Stream in Canada's Oil Sands Region

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Environments

Supplemental Tables

Supplemental Table S1. Environmental covariates; WT=water temperature; AT=air temperature; SD=stream discharge; P=precipitation; WS=wind speed; WG=wind gusts; \bar{x} = mean; \tilde{x} =median; values of environmental covariates by site shown in SI Figures 1-3.

Season	Period	Estimator	WT	AT	SD	P	WS	WG
Summer	August 4 to start of fishing	Mean	WT1- \bar{x}	AT1- \bar{x}	SD1- \bar{x}	P1- \bar{x}	WS1- \bar{x}	
		Median	WT1- \tilde{x}	AT1- \tilde{x}	SD1- \tilde{x}		WS1- \tilde{x}	
		75 th p-tile				P1-75		WG1-75
		99 th p-tile				P1-99		WG1-99
		99.9 th p-tile						WG1-999
		Sum				P1-TP		
		Count				P1-RD		
	60 days prior to fish collection	Mean		AT2- \bar{x}	SD2- \bar{x}	P2- \bar{x}	WS2- \bar{x}	
		Median		AT2- \tilde{x}	SD2- \tilde{x}		WS2- \tilde{x}	
		75 th p-tile				P2-75		WG2-75
		99 th p-tile				P2-99		WG2-99
		99.9 th p-tile						WG2-999
		Sum				P2-TP		
		Count				P2-RD		
	June 1- August 31	Mean		AT3- \bar{x}	SD3- \bar{x}	P3- \bar{x}	WS3- \bar{x}	
		Median		AT3- \tilde{x}	SD3- \tilde{x}		WS3- \tilde{x}	
		75 th p-tile				P3-75		WG3-75
		99 th p-tile				P3-99		WG3-99
		99.9 th p-tile						WG3-999
		Sum				P3-TP		
		Count				P3-RD		
	June 1- first fishing day	Mean		AT4- \bar{x}	SD4- \bar{x}	P4- \bar{x}	WS4- \bar{x}	
		Median		AT4- \tilde{x}	SD4- \tilde{x}		WS4- \tilde{x}	
		75 th p-tile				P4-75		WG4-75
		99 th p-tile				P4-99		WG4-99
		99.9 th p-tile						WG4-999
		Sum				P4-TP		
		Count				P4-RD		
Spring	April 1- June 30	Mean		SP-MT	SP-SD	SP-MP		
		75 th p-tile				SP-75		
		99 th p-tile				SP-99		
		Sum				SP-TP		
		Count				SP-RD		

Supplemental Table S2. Industrial variable names and codes.

Code	Feature name	Code	Feature name
HM-CB-P	Horizon mine crude bitumen production	SBM-CB-FW	Suncor Basemine crude bitumen flared/wasted
HM-DN-F	Horizon mine diluent naphtha fuel	SBM-CB-P	Suncor Basemine crude bitumen production
HM-DN-FW	Horizon mine diluent naphtha flared/wasted	SBM-DN-FW	Suncor Basemine diluent naphtha flared/wasted
HM-IH-P	Horizon mine intermediate hydrocarbon production	SBM-NG-F	Suncor Basemine natural gas fuel
HM-NG-F	Horizon mine natural gas fuel	SBM-NG-PU	Suncor Basemine natural gas plant use
HM-NG-FW	Horizon mine natural gas flared/wasted	SBM-OS-M	Suncor Basemine oil sand mined
HM-NG-PU	Horizon mine natural gas plant use	SBM-PC-F	Suncor Basemine petroleum coke fuel
HM-OS-M	Horizon mine oil sand mined	SBM-PC-P	Suncor Basemine petroleum coke production
HM-PC-P	Horizon mine petroleum coke production	SBM-PC-SP	Suncor Basemine petroleum coke stockpiled
HM-PC-SP	Horizon mine petroleum coke stockpiled	SBM-PG-F	Suncor Basemine process gas fuel
HM-PG-F	Horizon mine process gas fuel	SBM-PG-FW	Suncor Basemine process gas flared/wasted
HM-PG-FW	Horizon mine process gas flared/wasted	SBM-PG-P	Suncor Basemine process gas production
HM-PG-P	Horizon mine process gas production	SBM-S-FW	Suncor Basemine sulphur flared/wasted
HM-S-FW	Horizon mine sulphur flared/wasted	SBM-S-P	Suncor Basemine sulphur production
HM-S-P	Horizon mine sulphur production	SBM-SCO-F	Suncor Basemine synthetic crude fuel
HM-SCO-F	Horizon mine synthetic crude fuel	SBM-SCO-FW	Suncor Basemine synthetic crude flared/wasted
HM-SCO-P	Horizon mine synthetic crude production	SBM-SCO-P	Suncor Basemine synthetic crude production
HS-BR	Husky Sunrise bitumen production	SFB-BR	Suncor Firebag bitumen production rate
HS-ST	Husky Sunrise Steam injection	SFB-ST	Suncor Firebag steam injection rate
JPM-CB-P	Jackpine Mine crude bitumen production	SML-CB-FW	Syncrude Mildred Lake crude bitumen flared/wasted
JPM-NG-F	Jackpine Mine natural gas fuel	SML-CB-P	Syncrude Mildred Lake crude bitumen production
JPM-OS-M	Jackpine Mine oil sand mined	SML-DN-FW	Syncrude Mildred Lake diluent naphtha flared/wasted
KM-CB-FW	Kearl Mine crude bitumen flared/wasted	SML-NG-F	Syncrude Mildred Lake natural gas fuel
KM-CB-P	Kearl Mine crude bitumen production	SML-OS-M	Syncrude Mildred Lake oil sand mined
KM-DN-F	Kearl Mine diluent naphtha fuel	SML-PC-F	Syncrude Mildred Lake petroleum coke fuel
KM-DN-FW	Kearl Mine diluent naphtha flared/wasted	SML-PC-P	Syncrude Mildred Lake petroleum coke production
KM-NG-F	Kearl Mine natural gas fuel	SML-PC-SP	Syncrude Mildred Lake petroleum coke stockpiled
KM-NG-FW	Kearl Mine natural gas flared/wasted	SML-PG-F	Syncrude Mildred Lake process gas fuel
KM-OS-M	Kearl Mine oil sand mined	SML-PG-FW	Syncrude Mildred Lake process gas flared/wasted
KM-SCO-F	Kearl Mine synthetic crude fuel	SML-PG-P	Syncrude Mildred Lake process gas production
MRM-CB-FW	Muskeg River Mine crude bitumen flared/wasted	SML-S-FW	Syncrude Mildred Lake sulphur flared/wasted
MRM-CB-P	Muskeg River Mine crude bitumen production	SML-S-P	Syncrude Mildred Lake sulphur production
MRM-DN-F	Muskeg River Mine diluent naphtha fuel	SML-SCO-F	Syncrude Mildred Lake synthetic crude fuel
MRM-DN-FW	Muskeg River Mine diluent naphtha flared/wasted	SML-SCO-P	Syncrude Mildred Lake synthetic crude production
MRM-NG-F	Muskeg River Mine natural gas fuel	SMR-BR	Suncor MacKay River bitumen production
MRM-NG-FW	Muskeg River Mine natural gas flared/wasted	SMR-ST	Suncor MacKay River steam injection
MRM-OS-M	Muskeg River Mine oil sand mined	WE-BR	West Ells Sunshine bitumen production
SAN-CB-P	Syncrude Aurora North crude bitumen production	WE-ST	West Ells steam injection
SAN-NG-F	Syncrude Aurora North natural gas fuel		
SAN-OS-M	Syncrude Aurora North oil sand mined		
SAN-SCO-F	Syncrude Aurora North Synthetic crude fuel		

Supplemental Table S3. Distances from oil sands project boundaries to fish sampling locations; arranged by distance from Lower Ells.

Facility type	Facility	Facility code	Distance of site to industrial facility (km)	
			Upper	Lower
Mine	Horizon Mine	HM	9	5
	Muskeg River Mine	MRM	16	6
	Aurora North Mine	SAN	18	7
	Mildred Lake Mine	SML	14	15
	Jackpine Mine	JPM	26	16
In situ	Suncor MacKay River (in situ)	SMR	15	22
Mine	Suncor Basemine	SBM	30	28
	Kearl Mine	KM	38	28
In situ	Husky Sunrise (in situ)	HS	45	36
	Suncor Firebag (in situ)	SFB	54	45
	Sunshine West Ells (in situ)	SWE	46	57

Supplemental table S4. Female Lake Chub metrics (mean \pm SD(n)); * denote significant difference at Lower site compared to Upper site ($p < 0.05$).

Site	Date	Age (year)	Length (cm)	Weight (g)	Gonad weight (g)	Liver weight (g)
Lower Ells	2013	1.1 \pm 0.55 (20)	73.4 \pm 10.9 (20)	4.39 \pm 2.28 (20)	0.35 \pm 0.29 (20)	0.09 \pm 0.05 (20)
	2014	0.95 \pm 0.39 (21)	81.9 \pm 8.17 (21)*	6.07 \pm 1.93 (21)*	0.32 \pm 0.19 (21)*	0.11 \pm 0.06 (21)*
	2015	2.2 \pm 1.0 (20)*	79.9 \pm 10.2 (20)	5.62 \pm 2.31 (20)	0.31 \pm 0.19 (20)*	0.11 \pm 0.05 (20)*
	2018	2.1 \pm 0.8 (18)	68.6 \pm 8.01 (20)*	3.07 \pm 0.91 (19)	0.12 \pm 0.08 (19)*	0.04 \pm 0.02 (19)
Upper Ells	2013	2.17 \pm 0.47 (12)	81.3 \pm 16.1 (12)	6.02 \pm 3.32 (12)	0.43 \pm 0.28 (12)	0.10 \pm 0.06 (12)
	2014	1.0 \pm 0.35 (17)	62.8 \pm 4.57 (18)	2.43 \pm 0.57 (18)	0.12 \pm 0.05 (18)	0.04 \pm 0.02 (18)
	2015	3.2 \pm 1.0 (20)	85.1 \pm 8.48 (20)	6.79 \pm 2.36 (20)	0.52 \pm 0.30 (20)	0.16 \pm 0.07 (19)
	2018	2.7 \pm 0.7 (16)	75.4 \pm 12.2 (20)	4.18 \pm 1.81 (19)	0.26 \pm 0.22 (20)	0.06 \pm 0.04 (19)

Supplemental table S5. Male Lake Chub metrics (mean \pm SD(n)); * denote significant difference at Lower site compared to Upper site ($p < 0.05$).

Site	Date	Age (year)	Length (cm)	Weight (g)	Gonad weight (g)	Liver weight (g)
Lower Ells	2013	1.5 \pm 0.7 (21)	72.0 \pm 8.83 (21)	3.97 \pm 1.68 (21)	0.03 \pm 0.02 (21)	0.07 \pm 0.03 (21)
	2014	0.9 \pm 0.6 (17)	80.6 \pm 7.04 (20)*	5.84 \pm 1.57 (20)*	0.05 \pm 0.02 (20)*	0.09 \pm 0.06 (20)*
	2015	1.5 \pm 0.8 (16)*	73.1 \pm 9.72 (16)	4.33 \pm 1.68 (16)	0.04 \pm 0.03 (16)	0.07 \pm 0.03 (16)
	2018	1.9 \pm 0.8 (18)*	65.2 \pm 4.66 (20)	2.78 \pm 0.66 (20)	0.02 \pm 0.01 (20)*	0.04 \pm 0.01 (20)
Upper Ells	2013	1.7 \pm 0.6 (11)	73.8 \pm 11.8 (12)	4.15 \pm 1.91 (12)	0.04 \pm 0.02 (12)	0.05 \pm 0.02 (12)
	2014	1.1 \pm 0.4 (20)	67.0 \pm 6.37 (20)	3.06 \pm 0.93 (20)	0.03 \pm 0.02 (20)	0.04 \pm 0.01 (20)
	2015	2.5 \pm 0.8 (20)	75.6 \pm 5.21 (20)	4.50 \pm 0.85 (20)	0.04 \pm 0.01 (20)	0.07 \pm 0.02 (20)
	2018	1.7 \pm 0.8 (17)	65.5 \pm 8.72 (20)	2.85 \pm 1.12 (20)	0.03 \pm 0.01 (20)	0.04 \pm 0.03 (20)

Supplemental table S6. p-values for OLS and GLM spatial comparisons (Lower Ells vs Upper Ells) of male and female lake chub collected in the Ells River in 2013-2015, and 2018; Int=intercept; yellow highlighting = slope with p-value <0.05; red highlighting = intercept with p-value <0.05; ES=effect size (%).

Inferential Statistic	Sex	Year	GW			LW			BW		
			Slope	Int.	CES	Slope	Int.	CES	Slope	Int	CES
OLS	F	2013	0.25	0.162	9.86	0.627	0.004	25.85	0.424	0.211	4.25
	F	2014	0.897	0.045	6.45	0.235	0.485	12.53	>0.99	0.026	11.31
	F	2015	0.809	0.008	-28.86	0.776	0.013	-21.33	0.71	0.744	-0.90
	F	2018	0.04	0.086	-27.10	0.487	0.202	5.75	0.535	0.091	0.76
	M	2013	0.147	0.347	-10.87	0.577	0.002	27.49	0.097	0.362	2.95
	M	2014	0.13	<0.001	-9.77	0.041	0.866	11.02	0.510	0.028	9.71
	M	2015	0.625	0.282	-9.37	0.047	0.129	10.02	0.619	0.331	3.51
	M	2018	0.218	0.002	-35.22	0.233	0.162	14.13	0.931	0.22	2.80
GLM	F	2013	0.355	0.138	9.86	0.789	0.005	25.85	0.893	0.058	4.25
	F	2014	0.012	0.534	6.45	0.168	0.455	12.53	0.027	0.002	11.31
	F	2015	0.217	0.005	-28.86	0.24	0.003	-21.33	0.884	0.988	-0.90
	F	2018	0.017	0.421	-27.10	0.601	0.184	5.75	0.716	0.013	0.76
	M	2013	0.202	0.502	-10.87	0.728	0.005	27.49	0.06	0.283	2.95
	M	2014	0.128	<0.001	-9.77	0.457	0.765	11.02	0.758	0.025	9.71
	M	2015	0.899	0.203	-9.37	0.038	0.382	10.02	0.552	0.721	3.51
	M	2018	0.054	0.003	-35.22	0.088	0.128	14.13	0.642	0.047	2.80

Supplemental table S7. p-values for OLS temporal comparisons of male and female lake chub collected in the Ells River in 2013-2015, and 2018; Int=intercept; yellow highlighting = slope with p-value <0.05; pink highlighting = intercept with p-value <0.05; ES=effect size (%).

Sex	Site	Ref Year	Test Year	GW			LW			BW		
				Slope	Int	ES	Slope	Int	ES	Slope	Int	ES
M	lower	2013	2014	0.303	0.077	0.89	0.122	0.021	-12.68	0.995	0.08	7.61
M	lower	2013	2015	0.455	0.588	3.19	0.964	0.307	-6.56	0.161	0.064	5.27
M	lower	2013	2018	0.009	0.533	-19.67	0.168	0.012	-16.89	0.741	0.545	-2.83
M	lower	2014	2015	0.979	0.163	2.28	0.162	0.124	7.01	0.308	0.411	-2.18
M	lower	2014	2018	<0.001	0.996	-20.37	0.049	0.831	-4.82	0.794	0.134	-9.70
M	lower	2015	2018	0.006	0.968	-22.15	0.221	0.081	-11.05	0.154	0.004	-7.69
M	upper	2013	2014	0.069	0.464	-0.35	0.511	0.621	0.27	0.437	0.802	0.98
M	upper	2013	2015	0.074	0.876	1.48	0.02	0.297	8.28	0.801	0.035	4.69
M	upper	2013	2018	0.482	0.824	10.53	0.514	0.385	-7.16	0.03	0.404	-2.69
M	upper	2014	2015	0.742	0.014	1.83	0.005	0.326	7.99	0.349	0.024	3.68
M	upper	2014	2018	0.013	0.549	10.92	0.308	0.179	-7.41	0.184	0.114	-3.63
M	upper	2015	2018	0.026	0.987	8.92	0.467	0.324	-14.26	0.046	0.029	-7.05
F	lower	2013	2014	0.804	<0.001	-30.49	0.013	0.002	-18.71	0.953	0.27	3.83
F	lower	2013	2015	0.937	<0.001	-28.90	0.342	0.045	-12.00	0.434	0.757	1.42
F	lower	2013	2018	0.104	<0.001	-48.67	0.409	<0.001	-31.38	0.428	0.105	-5.69
F	lower	2014	2015	0.769	0.327	2.29	0.054	0.062	8.25	0.378	0.419	-2.33
F	lower	2014	2018	0.205	0.274	-26.15	0.219	0.959	-15.58	0.355	0.016	-9.18
F	lower	2015	2018	0.115	0.655	-27.81	0.844	0.022	-22.02	0.942	0.056	-7.01
F	upper	2013	2014	0.444	0.832	-28.26	0.907	0.409	-9.08	0.482	0.652	-2.75
F	upper	2013	2015	0.26	0.996	9.80	0.534	0.003	40.77	0.765	0.142	6.69
F	upper	2013	2018	0.078	0.138	-22.65	0.085	0.042	-18.34	0.544	0.84	-2.42
F	upper	2014	2015	0.983	0.108	53.07	0.687	0.099	54.83	0.418	0.573	9.71
F	upper	2014	2018	0.877	<0.001	7.83	0.417	0.073	-10.18	0.228	0.111	0.34
F	upper	2015	2018	0.785	0.293	-29.55	0.533	<0.001	-41.99	0.947	0.077	-8.54

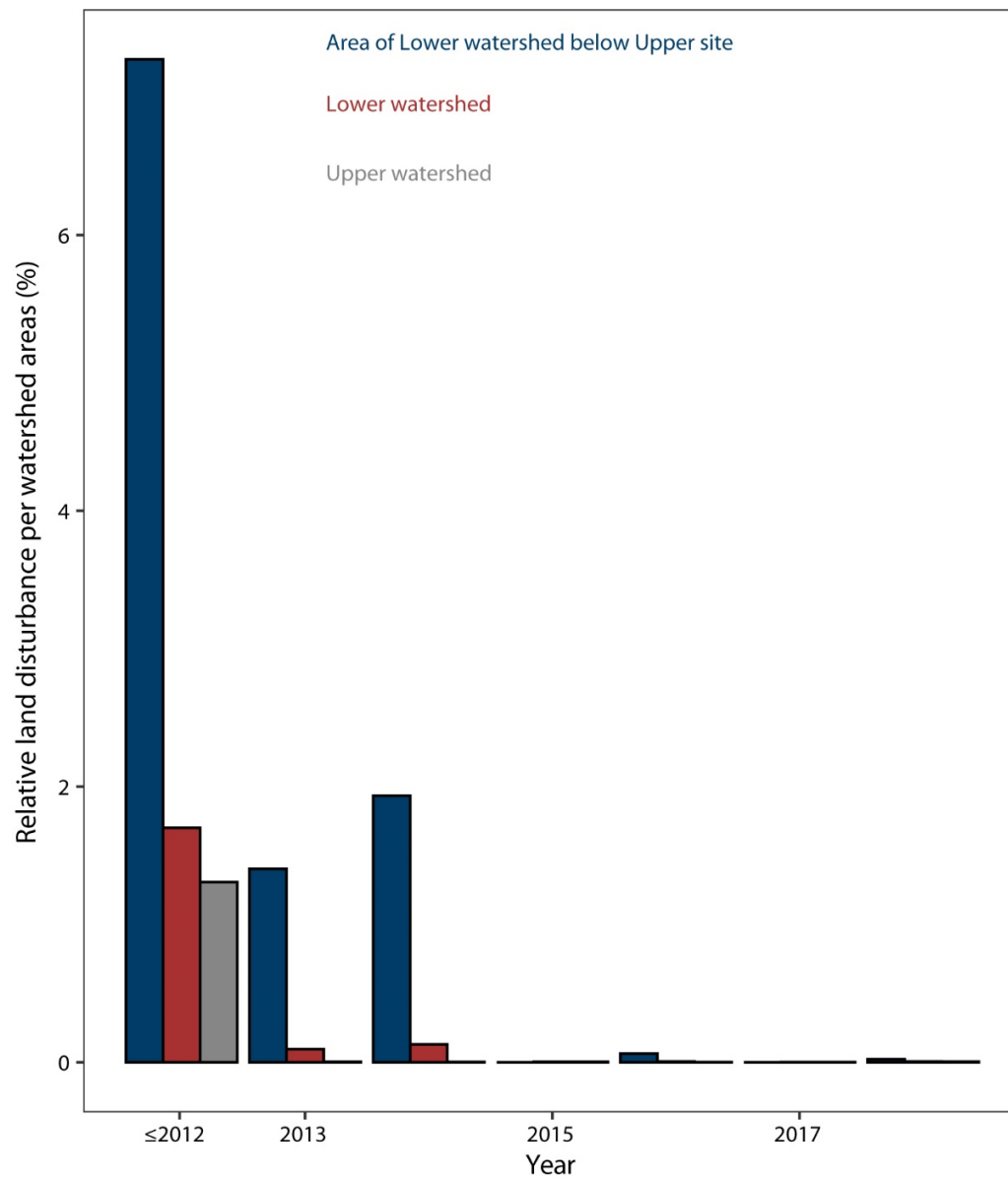
Supplemental table S8. p-values for GLM temporal comparisons of male and female lake chub collected in the Ells River in 2013-2015, and 2018; Int=intercept; yellow highlighting = slope with p-value <0.05; pink highlighting = intercept with p-value <0.05; ES=effect size (%).

Sex	Site	Ref Year	Test Year	GW			LW			BW		
				Slope	Int	ES	Slope	Int	ES	Slope	Int	ES
M	lower	2013	2014	0.661	0.128	0.89	0.215	0.09	-12.68	0.744	0.052	7.61
		2013	2015	0.606	0.814	3.19	0.867	0.506	-6.56	0.215	0.087	5.27
		2013	2018	0.069	0.226	-19.67	0.697	0.005	-16.89	0.131	0.465	-2.83
		2014	2015	0.842	0.095	2.28	0.312	0.219	7.01	0.531	0.288	-2.18
		2014	2018	0.009	0.946	-20.37	0.357	0.631	-4.82	0.142	0.125	-9.70
		2015	2018	0.031	0.527	-22.15	0.64	0.058	-11.05	0.018	0.008	-7.69
	upper	2013	2014	0.005	0.773	-0.35	0.596	0.704	0.27	0.076	0.892	0.98
		2013	2015	0.053	0.638	1.48	0.007	0.053	8.28	0.959	0.008	4.69
		2013	2018	0.262	0.87	10.53	0.022	0.722	-7.16	<0.001	0.574	-2.69
		2014	2015	0.301	0.034	1.83	0.056	0.357	7.99	0.108	0.016	3.68
		2014	2018	0.096	0.515	10.92	0.066	0.293	-7.41	0.009	0.053	-3.63
		2015	2018	0.426	0.339	8.92	0.401	0.967	-14.26	<0.001	0.103	-7.05
F	lower	2013	2014	0.407	0.005	-30.49	0.336	0.064	-18.71	0.147	0.167	3.83
		2013	2015	0.501	0.004	-28.90	0.723	0.141	-12.00	0.589	0.662	1.42
		2013	2018	0.033	0.002	-48.67	0.027	<0.001	-31.38	0.321	0.13	-5.69
		2014	2015	0.721	0.818	2.29	0.426	0.407	8.25	0.221	0.235	-2.33
		2014	2018	0.002	0.949	-26.15	0.207	0.427	-15.58	0.01	0.006	-9.18
		2015	2018	0.001	0.676	-27.81	0.025	0.014	-22.02	0.057	0.036	-7.01
	upper	2013	2014	0.006	0.499	-28.26	0.114	0.474	-9.08	0.238	0.714	-2.75
		2013	2015	0.52	0.251	9.80	0.333	0.001	40.77	0.66	0.024	6.69
		2013	2018	0.069	0.587	-22.65	0.093	0.362	-18.34	0.075	0.583	-2.42
		2014	2015	0.001	0.038	53.07	0.062	0.001	54.83	0.109	0.122	9.71
		2014	2018	0.041	0.116	7.83	0.32	0.178	-10.18	0.596	0.037	0.34
		2015	2018	0.009	0.1	-29.55	0.014	<0.001	-41.99	0.027	0.05	-8.54

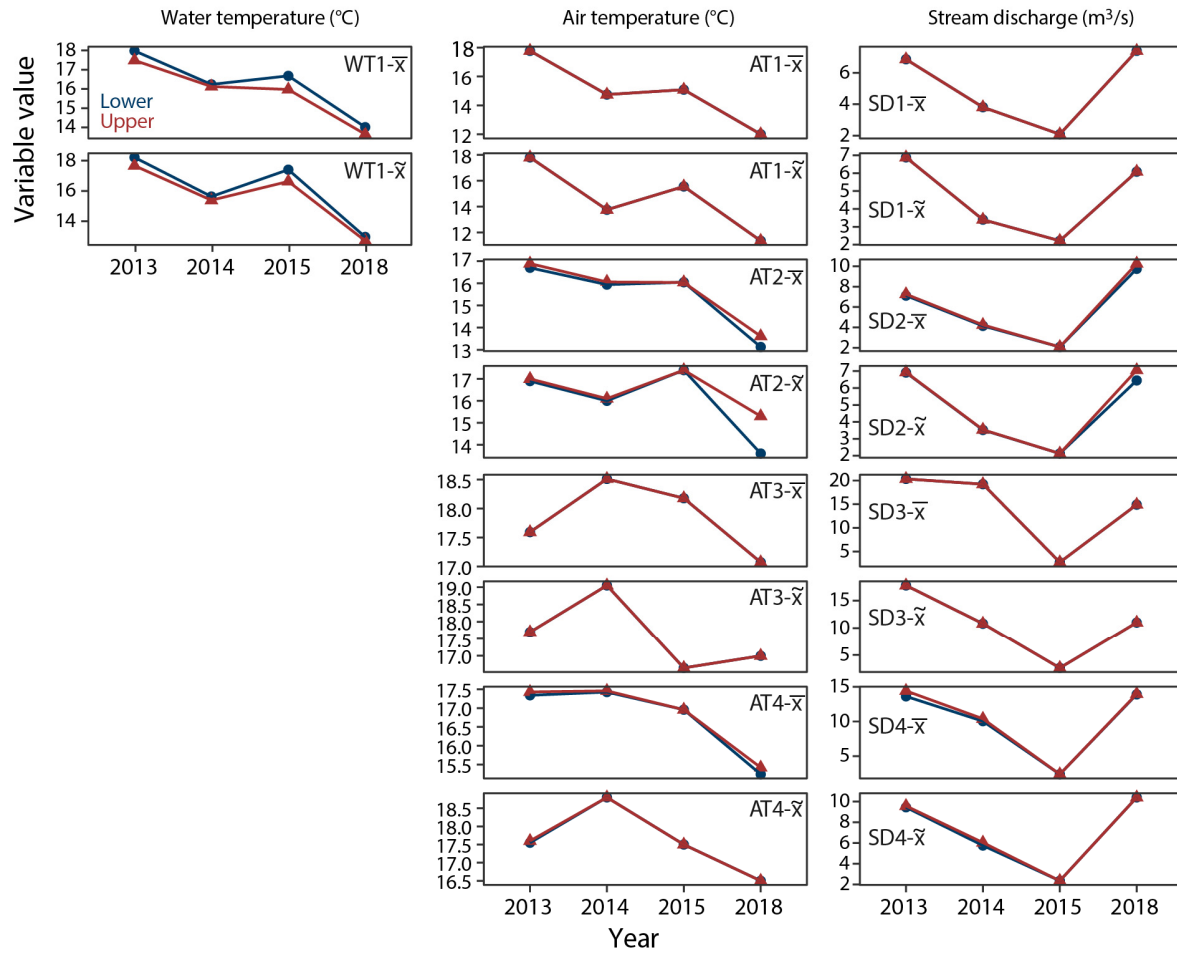
Supplemental table S9. GLM p-values for grouped Reference years (2013-2015) compared to 2018; yellow highlighting = slope with p-value <0.05; pink highlighting = intercept with p-value <0.05; ES=effect size (%).

Sex	Site	Ref. Year	Test Year	GW			LW			BW		
				Slope	Int.	ES	Slope	Int	ES	Slope	Int	ES
M	Lower	2013-2015	2018	0.043	0.421	-20.62	0.669	0.042	-11.31	0.128	0.02	-6.70
	Upper	2013-2015	2018	0.992	0.459	10.05	0.007	0.149	-10.11	<0.001	0.013	-4.77
F	Lower	2013-2015	2018	0.001	0.024	-35.86	0.011	<0.001	-23.43	0.115	0.006	-7.35
	Upper	2013-2015	2018	0.087	0.253	-17.49	0.562	0.01	-27.39	0.147	0.229	-4.04

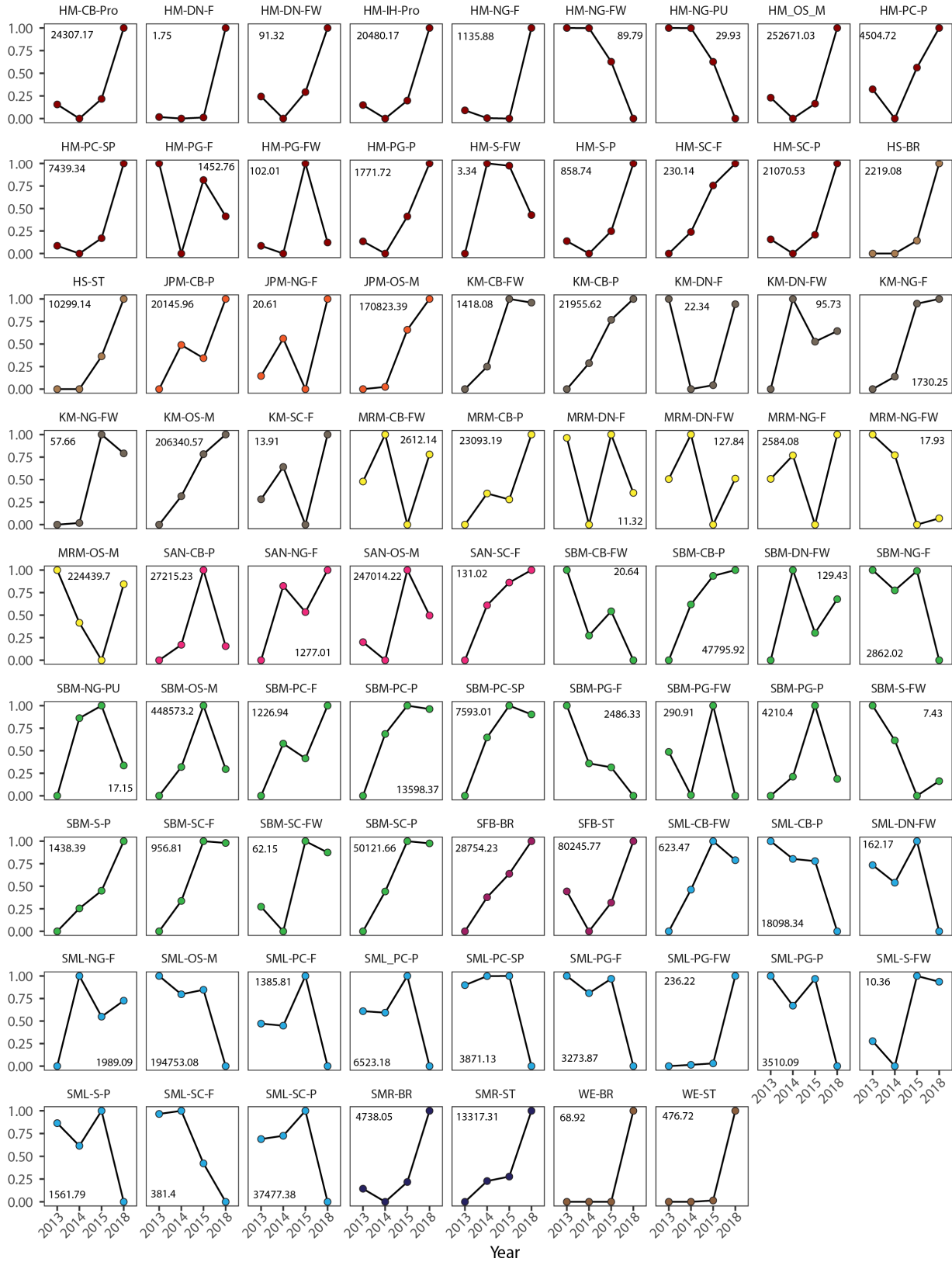
Supplemental Figures



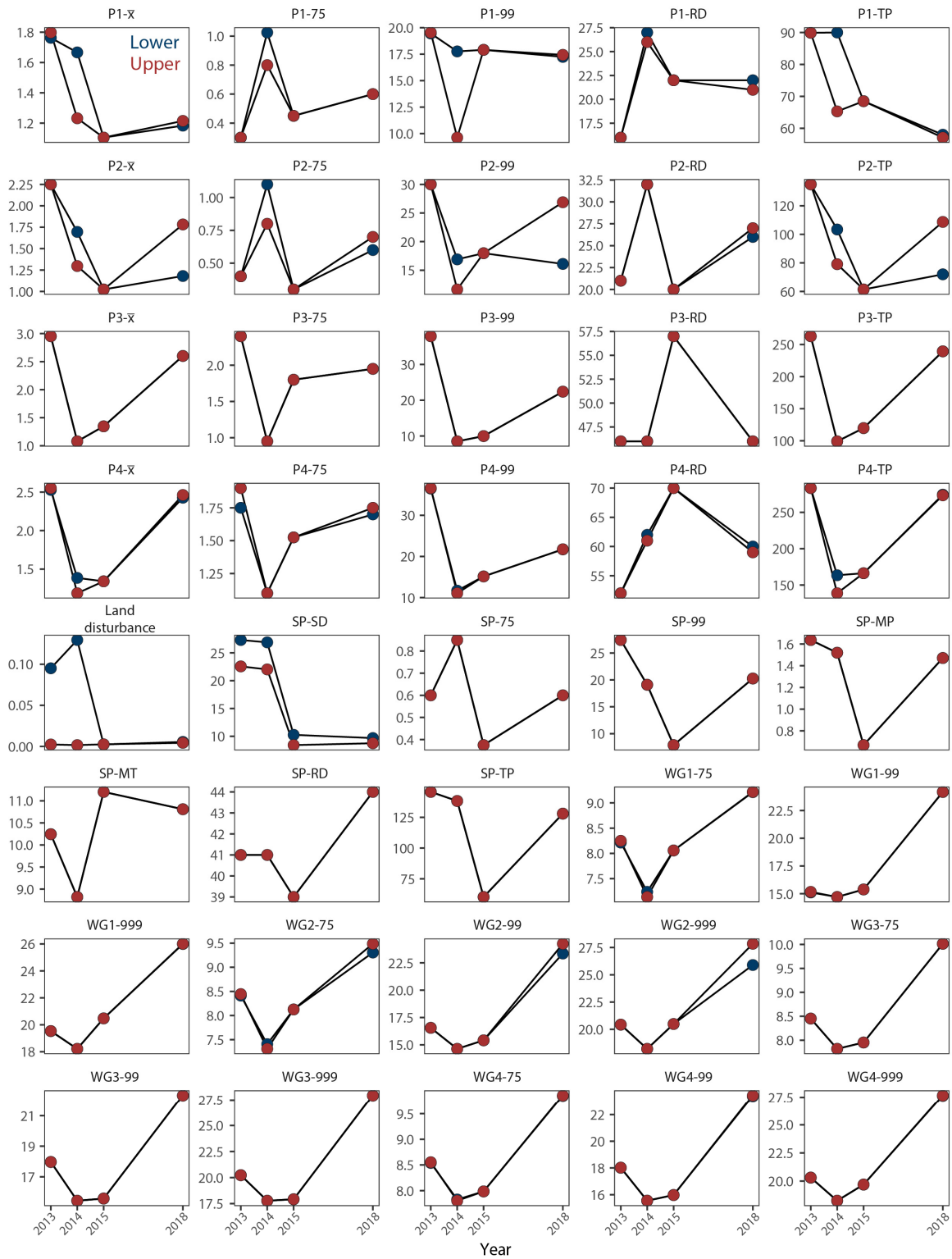
Supplemental Figure S1. Relative land disturbance (%) in watershed above Upper site (grey), above the Lower site (red) and area of lower watershed below the Upper location (blue) over time.



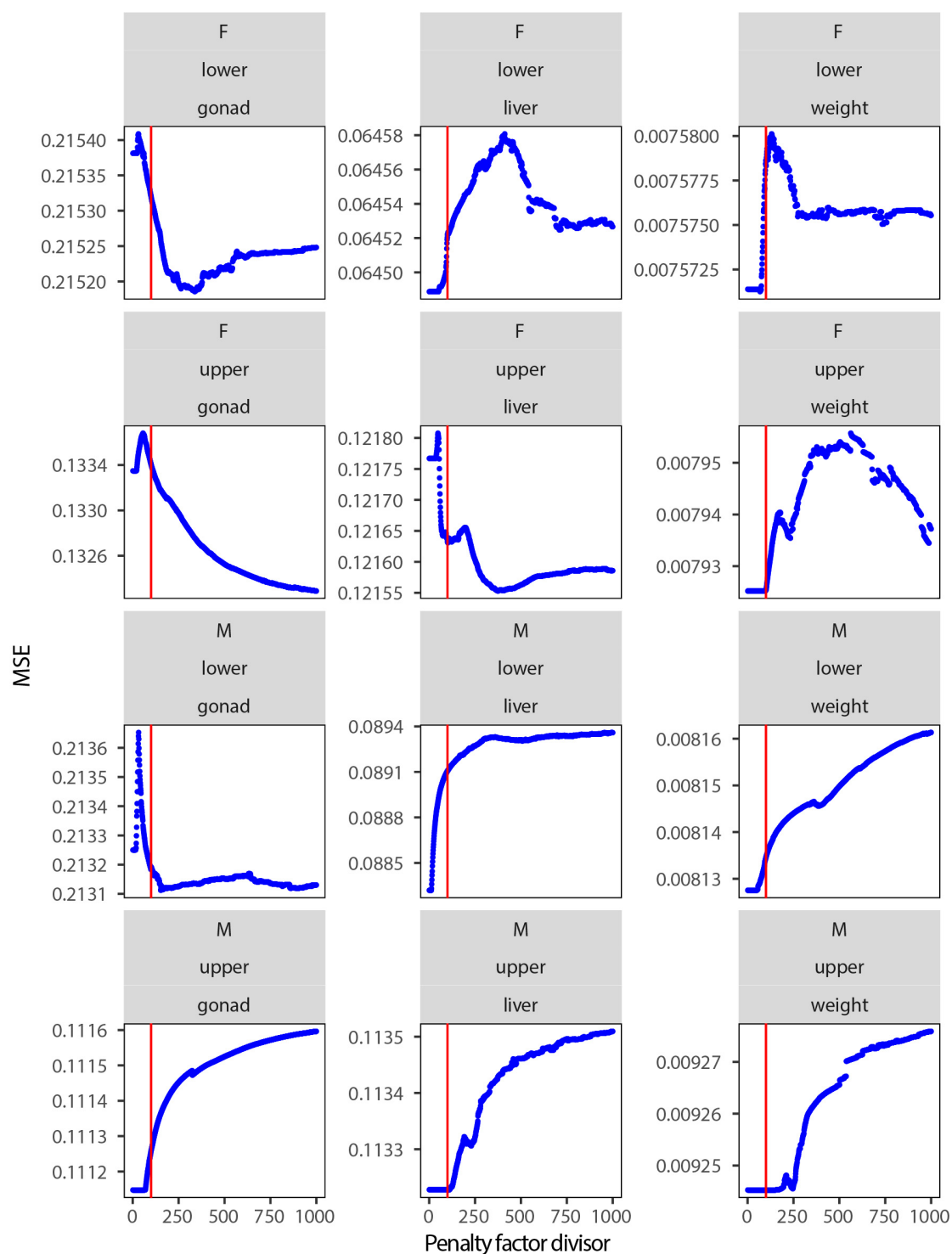
Supplemental Figure S2. Plots of environmental covariates for the Upper and Lower Ells locations; SD values are from the Upper Location; WT=water temperature; AT=air temperature; SD=stream discharge.



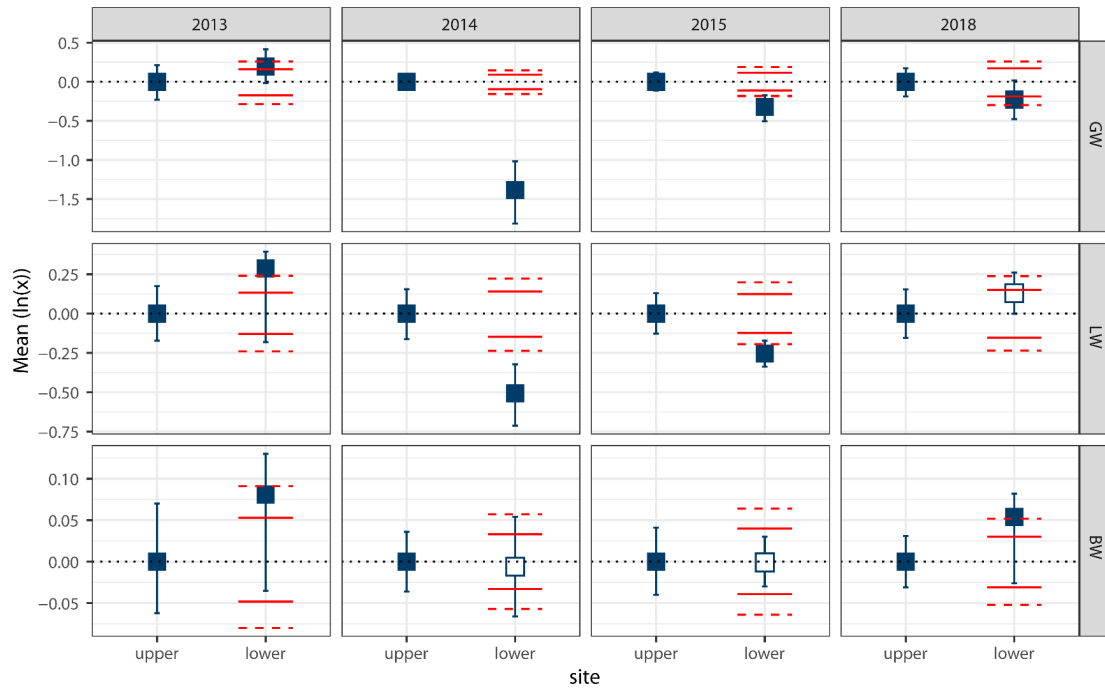
Supplemental Figure S3. Industrial covariates; values within each pane are the 2013-2015+2018 (monthly) means; values standardized to 0-1.



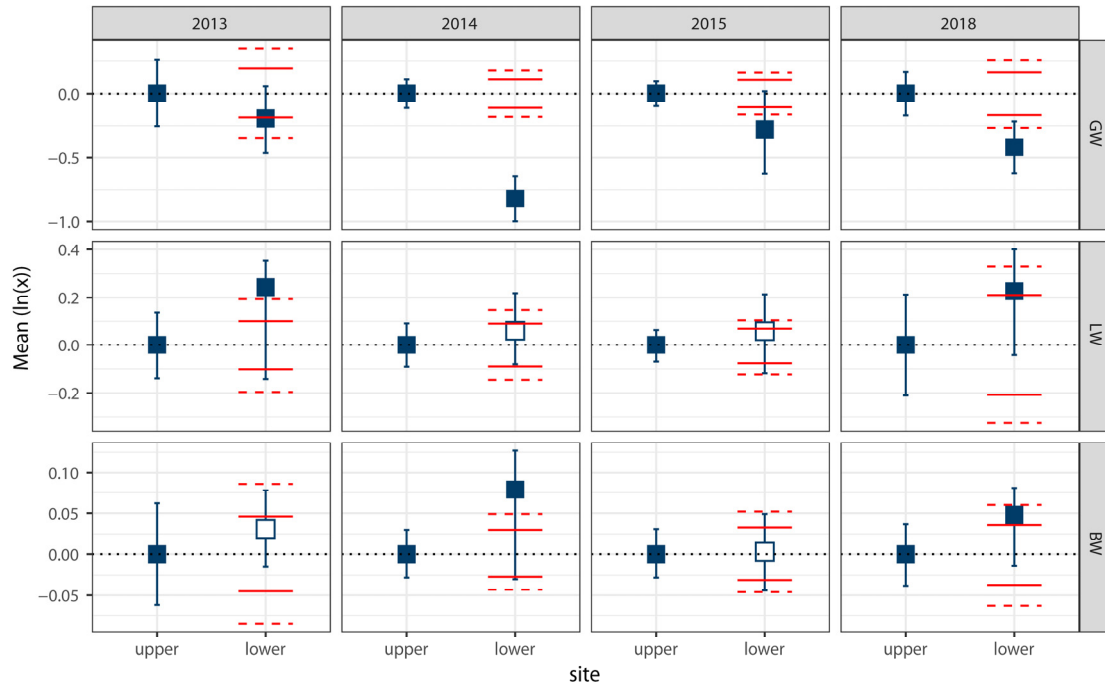
Supplemental Figure S4. Extra covariates included in ENV+IND models (and land disturbance) which may capture some industrial influence.



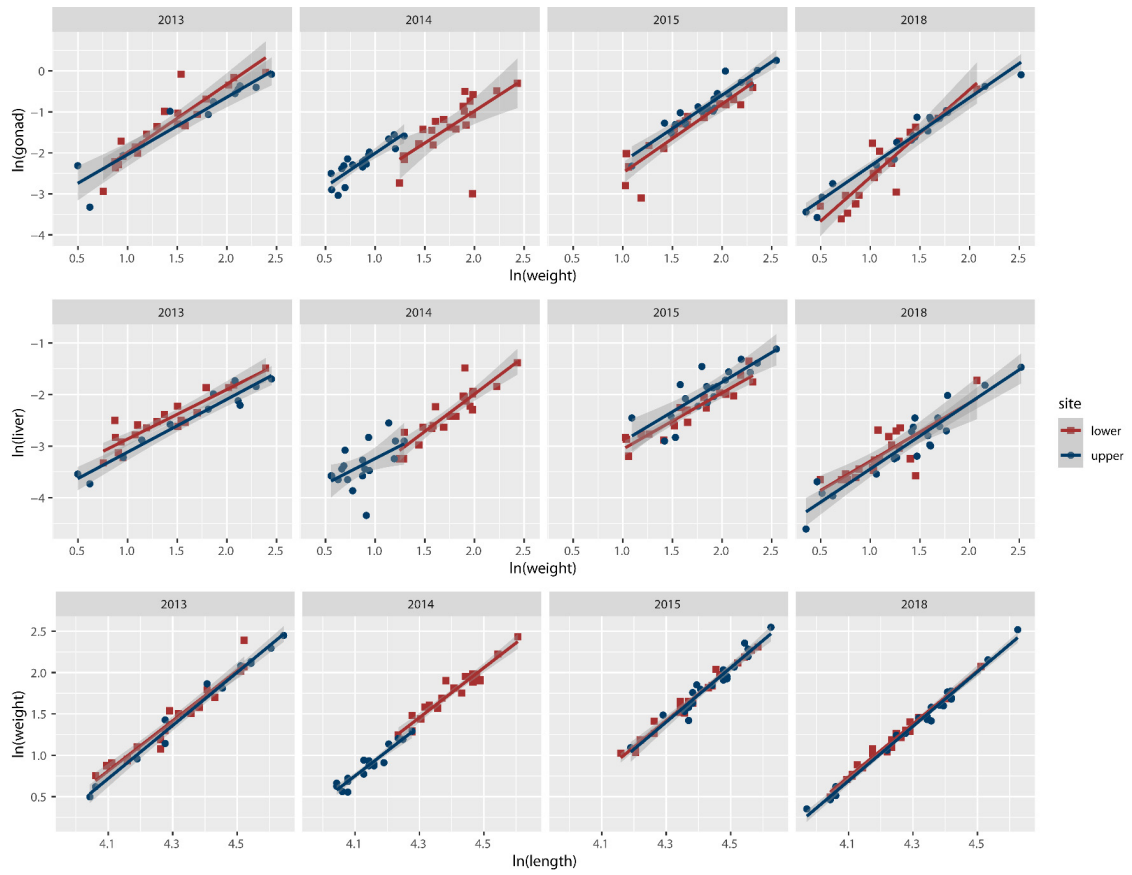
Supplemental Figure S5. Mean squared error for 1,000 Elastic net model runs using penalty factors based on distance in km divided by 1 to 1,000 of Upper and Lower sites to industrial facilities.



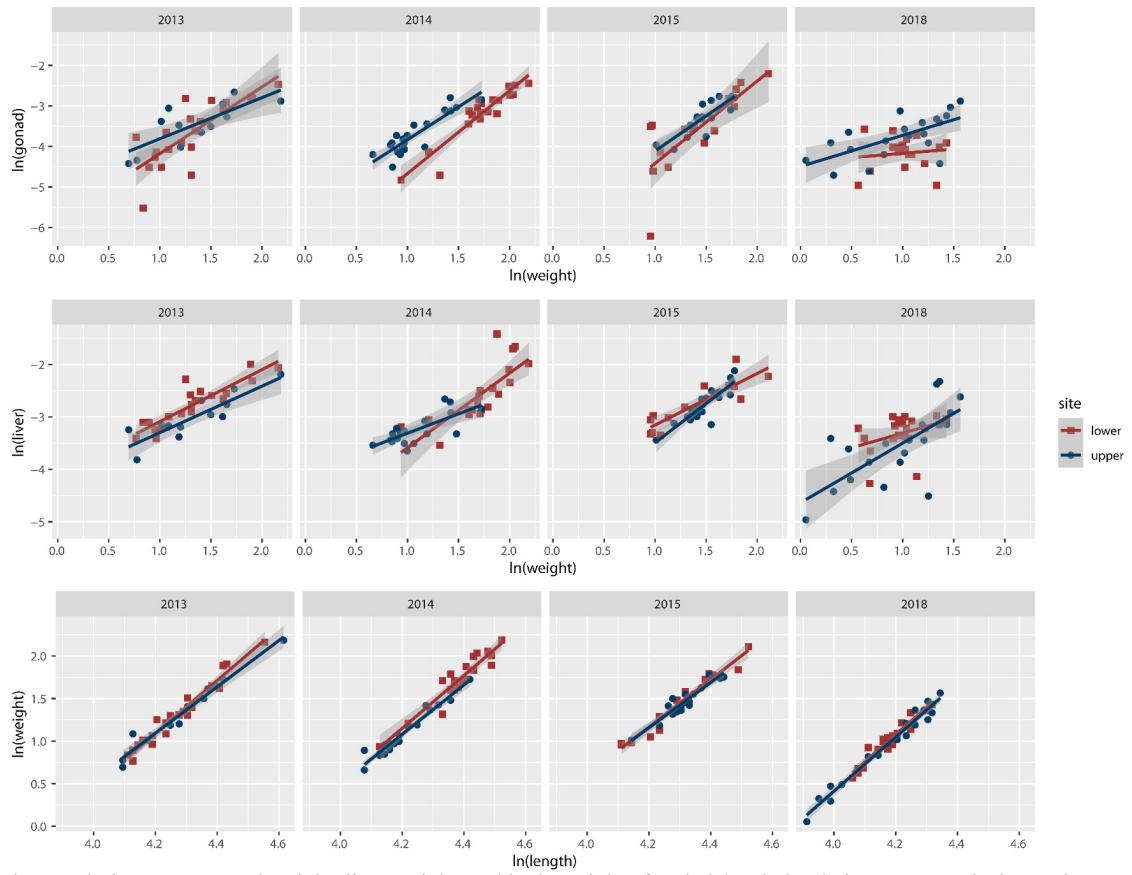
Supplemental Figure S6. Mean residual gonad weight (GW), liver weight (LW), and body weight (BW) of females (with central 95% confidence interval) at the upper and Lower Ells locations; residual GW, LW, and BW at the Lower site calculated using models estimated using fish from the Upper location; Redlines showing expected range of mean residuals at the Lower site given the sample size for the Lower site.



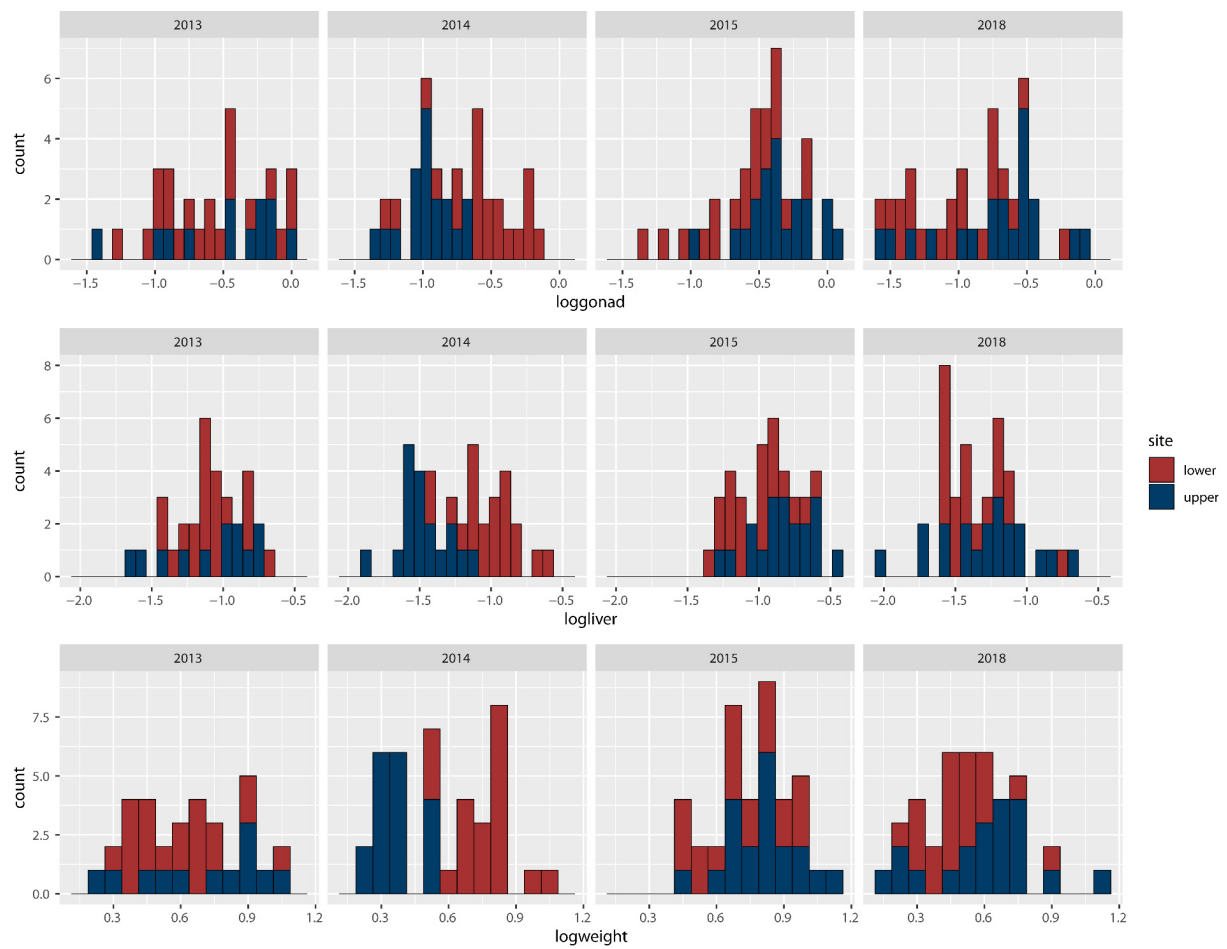
Supplemental Figure S7. Mean residual gonad weight (GW), liver weight (LW), and body weight (BW) of males (with central 95% confidence interval) at the Upper and Lower Ells locations; residual GW, LW, and BW at the Lower site calculated using models estimated using fish from the Upper location; Redlines showing expected range of mean residuals at the Lower site given the sample size for the Lower site.



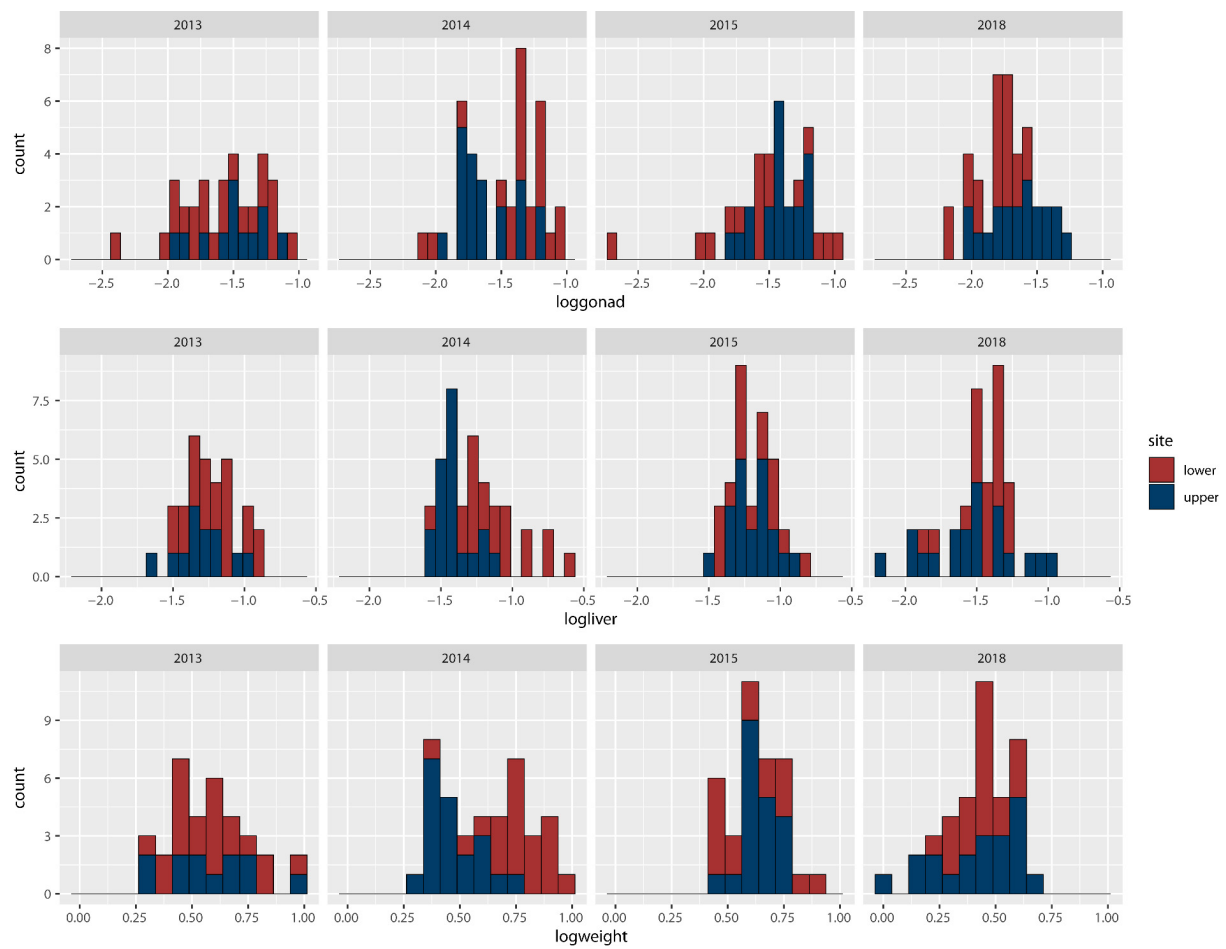
Supplemental Figure S8. Gonad weight, liver weight, and body weight of female lake chub relative to anatomical covariates at the Lower and Upper Ells locations in 2013:2015, 2018.



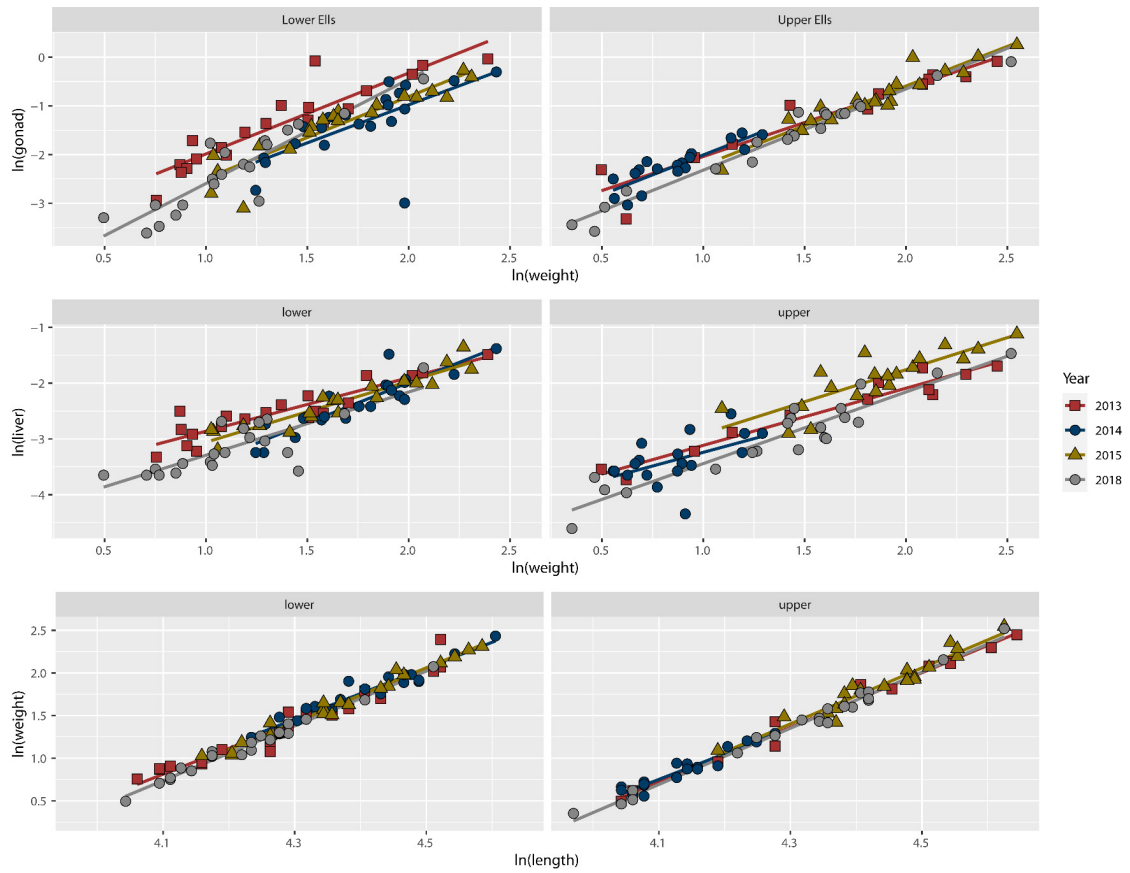
Supplemental Figure S9. Gonad weight, liver weight, and body weight of male lake chub relative to anatomical covariates at the lower and upper Ells locations by year 2013:2015, 2018.



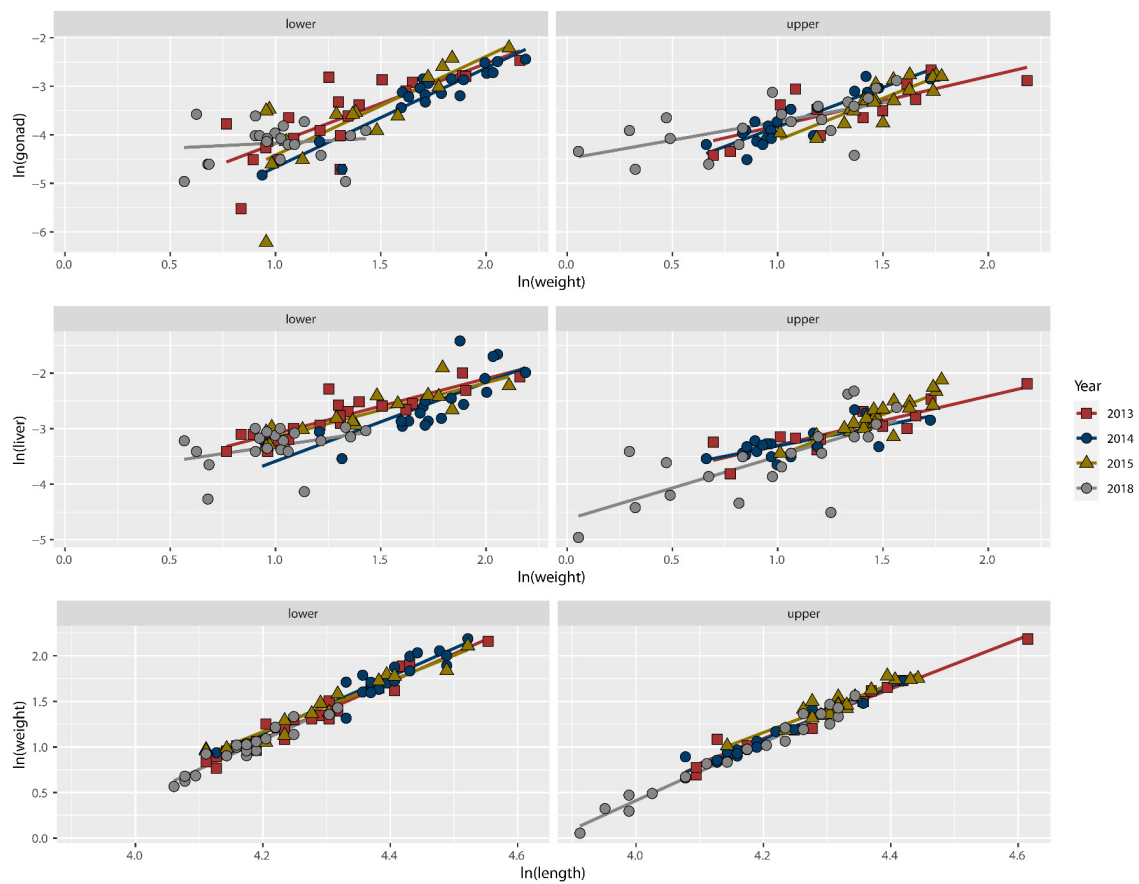
Supplemental Figure S10. Histograms of female lake chub gonad weight, liver weight, and body weight.



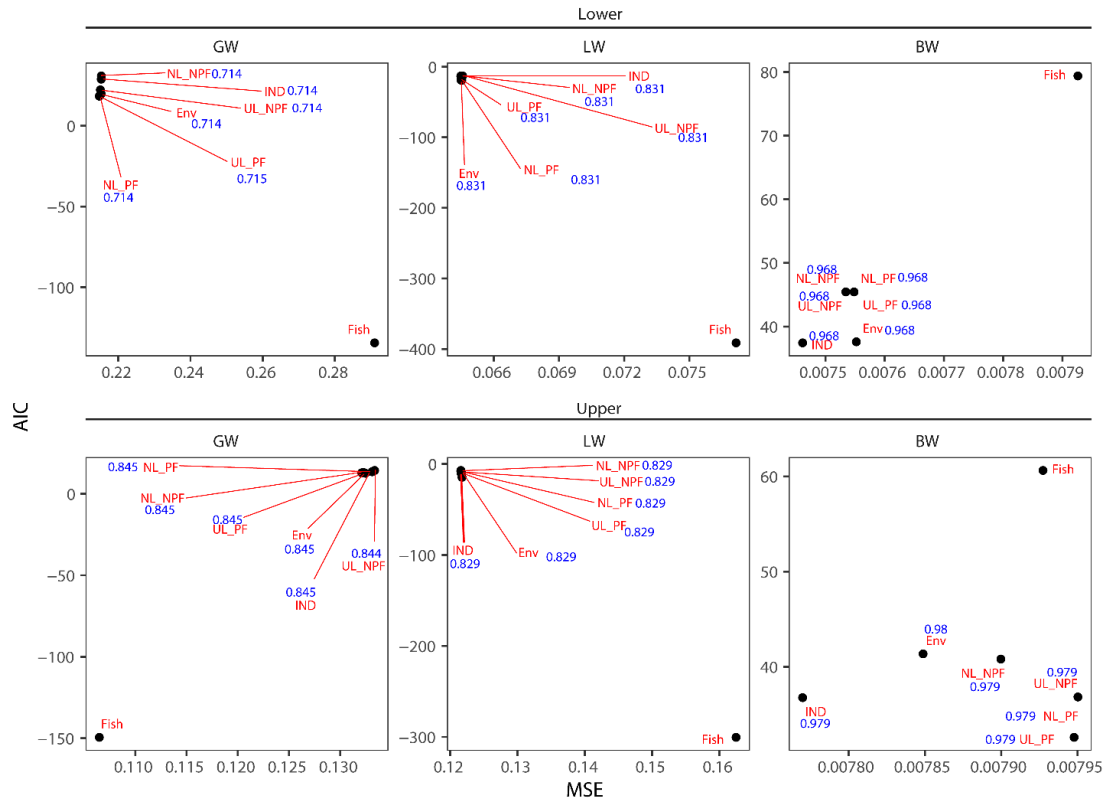
Supplemental Figure S11. Histograms of male lake chub gonad weight, liver weight, and body weight.



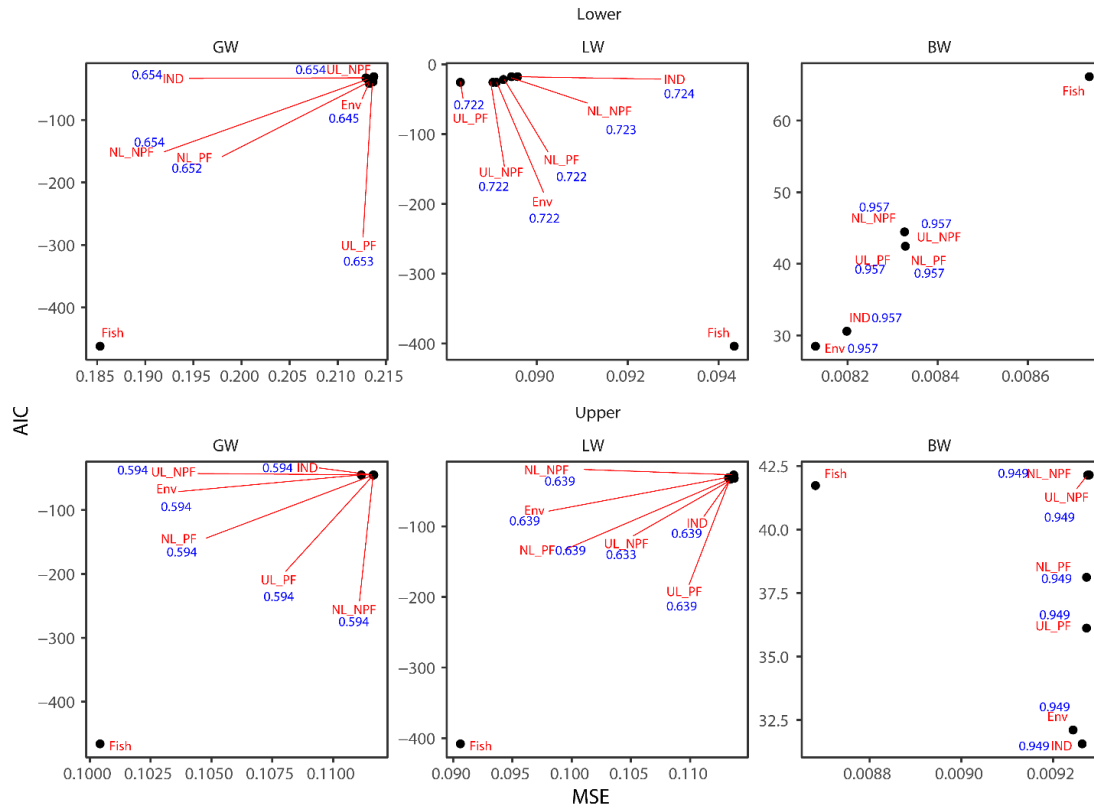
Supplemental Figure S12. Gonad weight, liver weight, and body weight of female lake chub relative to anatomical covariates in 2013, 2014, 2015, and 2018 by location (lower and upper Ells).



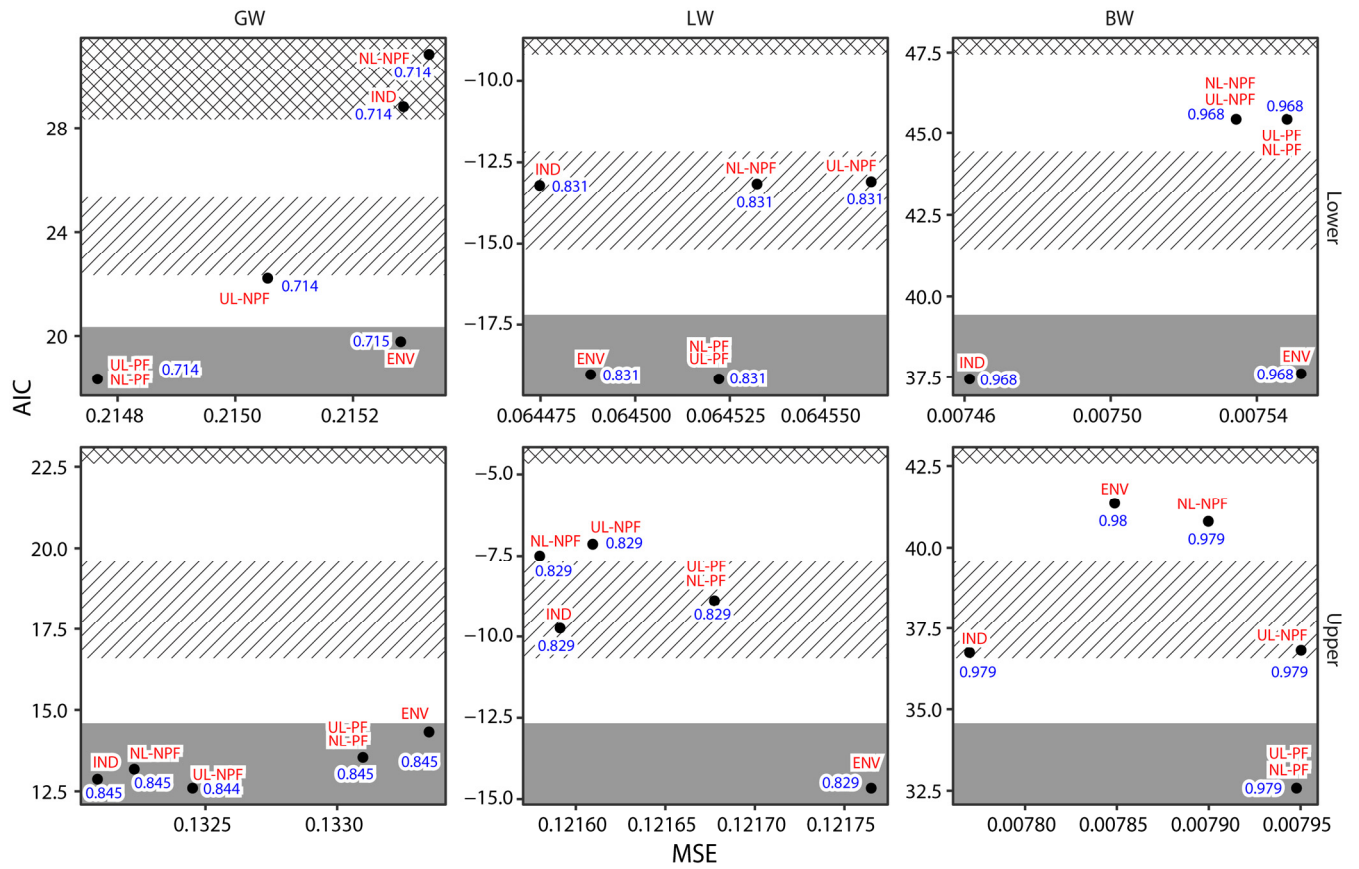
Supplemental Figure S13. Gonad weight, liver weight, and body weight of male lake chub relative to anatomical covariates in 2013, 2014, 2015, and 2018 by location (lower and upper Ells).



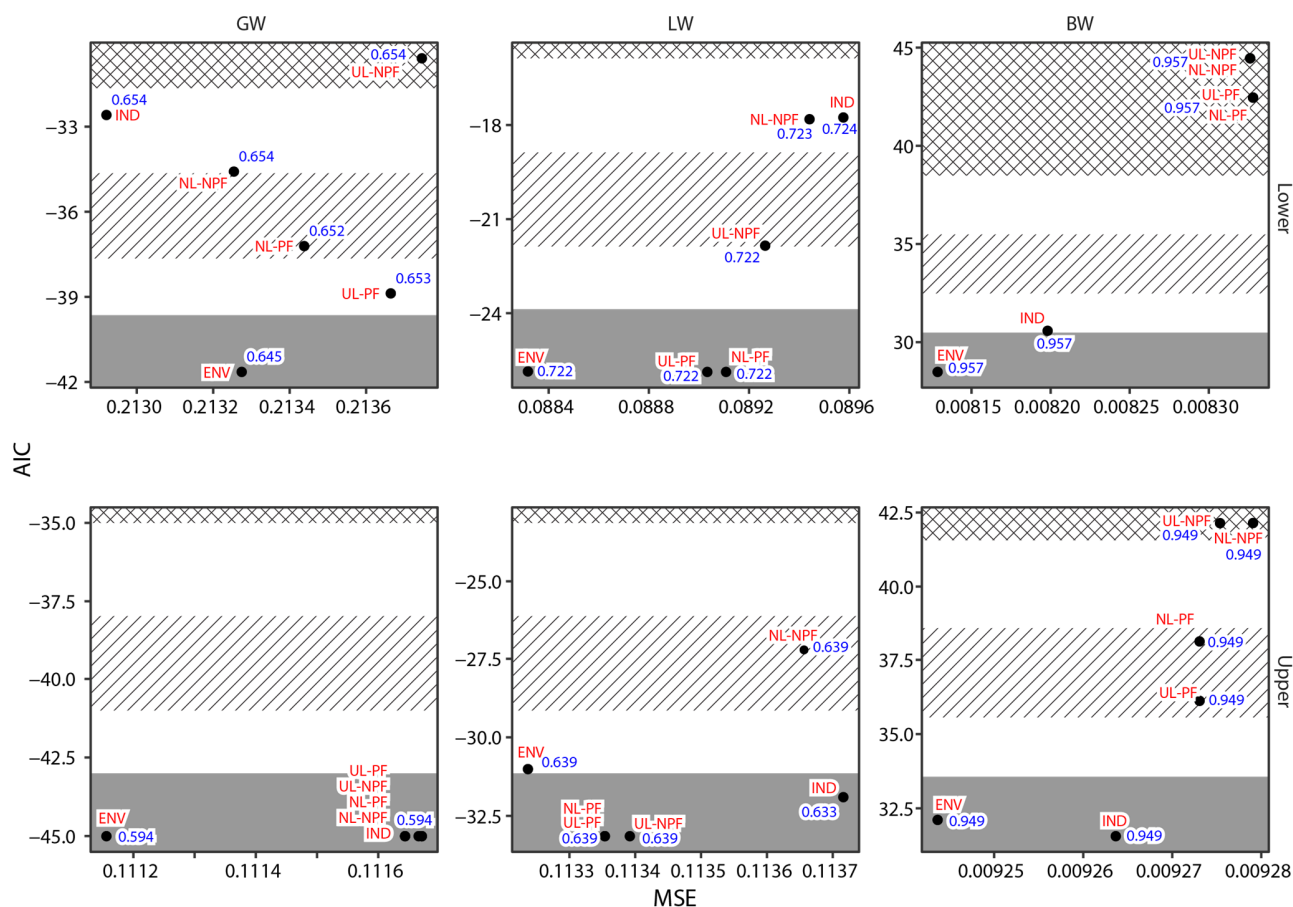
Supplemental Figure S14. Female model stats with FISH GLM results; AIC=Akaike's Information Criterion; MSE=Mean Squared Error; blue values denote Deviance Ratios of regularized regression models; 'Fish' =models with no environmental or industrial covariates; 'ENV' includes environmental covariates only; IND includes industrial covariates only (with no limits and no penalty factors); ENV+IND with no limits and no penalty factors (NL_NPF); ENV+IND with no limits and penalty factors (NL_PF); ENV+IND with upper limits and no penalty factors (UL_NPF); ENV+IND with upper limits and penalty factors (UL_PF).



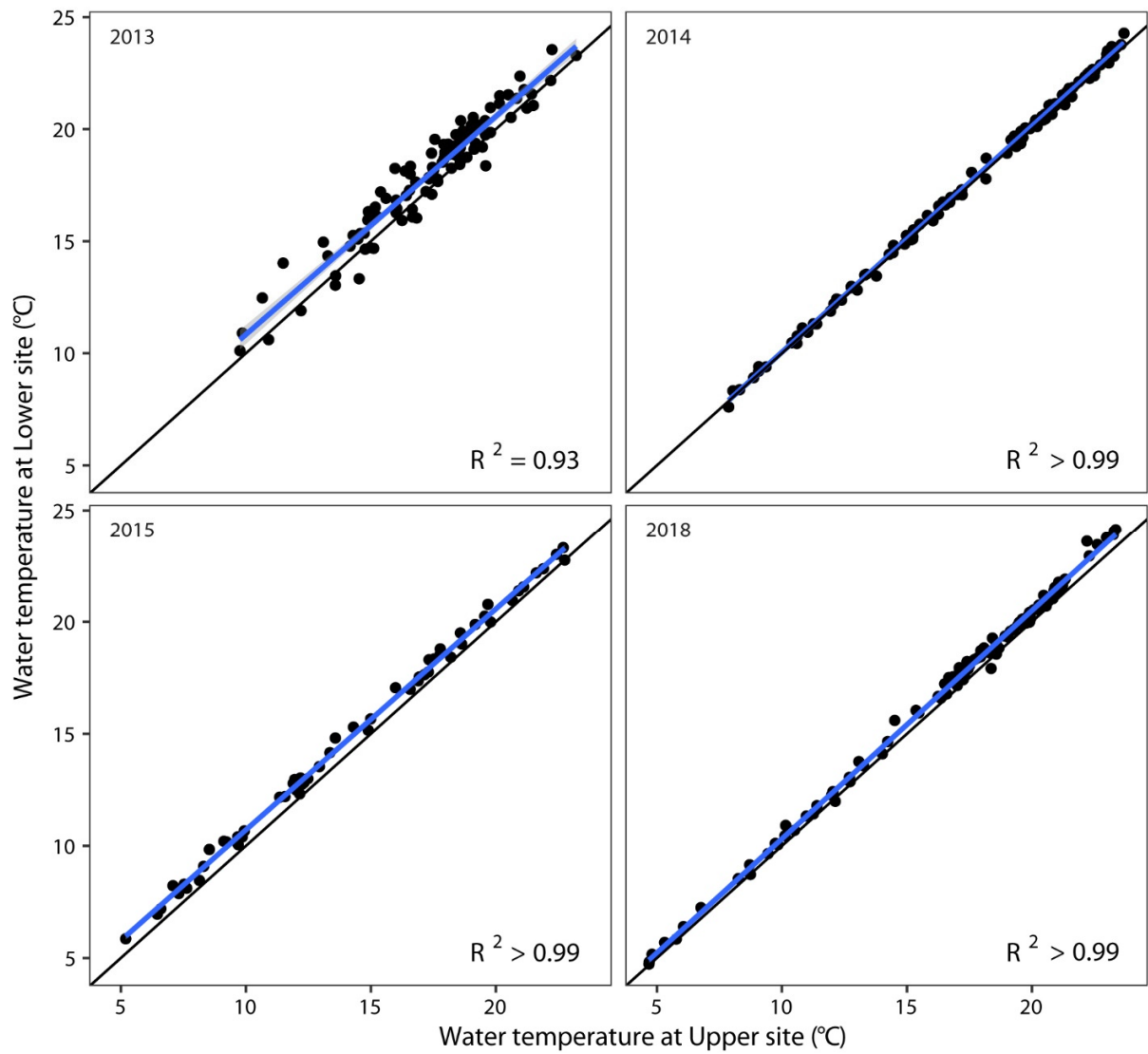
Supplemental Figure S15. Male model stats with FISH GLM results; AIC=Akaike's Information Criterion; MSE=Mean Squared Error; blue values denote Deviance Ratios of regularized regression models; 'Fish' =models with no environmental or industrial covariates; 'ENV' includes environmental covariates only; IND includes industrial covariates only (with no limits and no penalty factors); ENV+IND with no limits and no penalty factors (NL_NPF); ENV+IND with no limits and penalty factors (NL_PF); ENV+IND with upper limits and no penalty factors (UL_NPF); ENV+IND with upper limits and penalty factors (UL_PF).



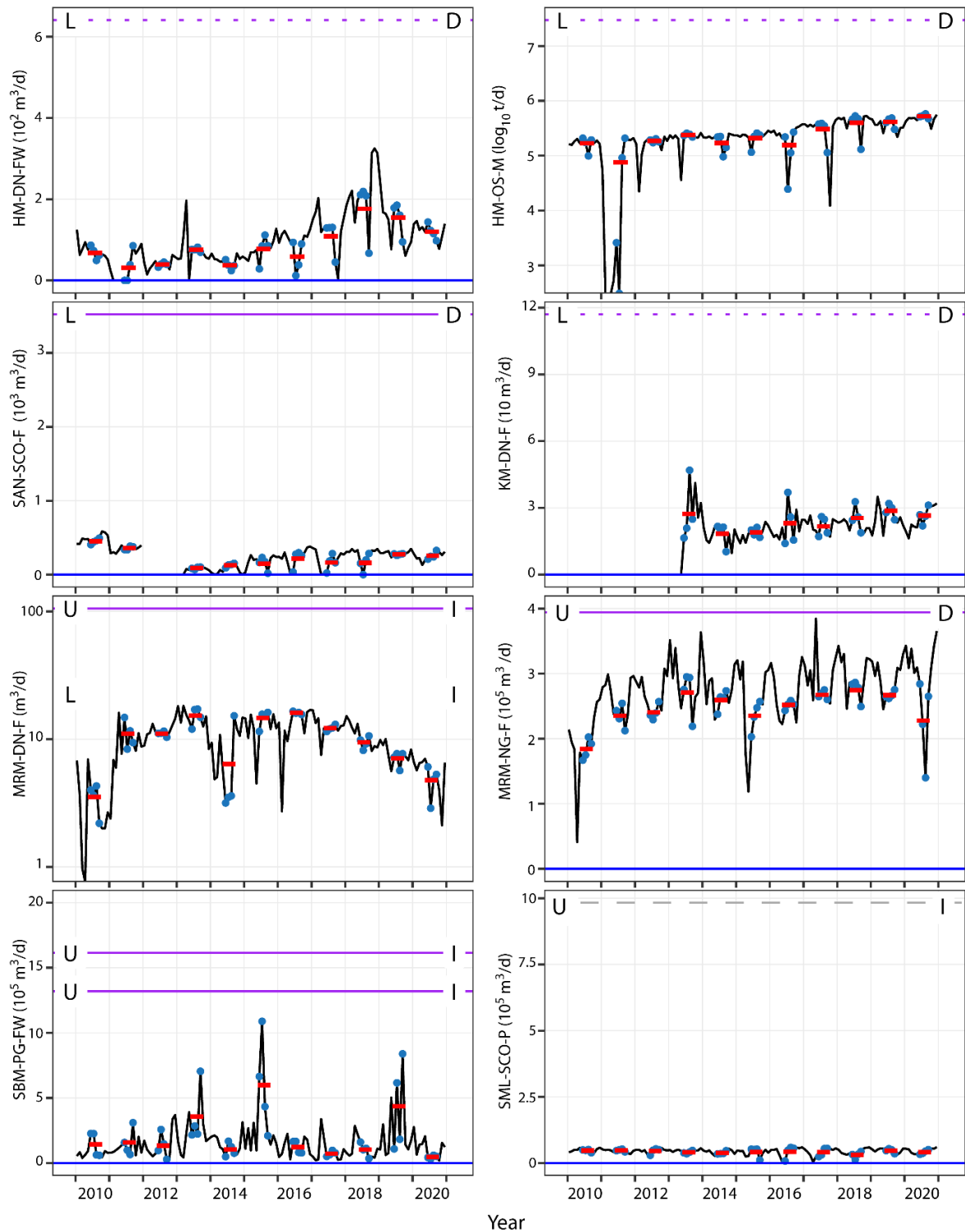
Supplemental Figure S16. AICs, MSEs, and Deviance ratios for model scenarios among female lake chub at the upper and lower locations; AIC=Akaike's Information Criterion; MSE=Mean Squared Error; blue values denote Deviance Ratios of regularized regression models; 'Fish' =models with no environmental or industrial covariates; 'ENV' includes environmental covariates only; IND includes industrial covariates only (with no limits and no penalty factors); ENV+IND with no limits and no penalty factors (NL-NPF); ENV+IND with no limits and penalty factors (NL-PF); ENV+IND with upper limits and no penalty factors (UL-NPF); ENV+IND with upper limits and penalty factors (UL-PF).



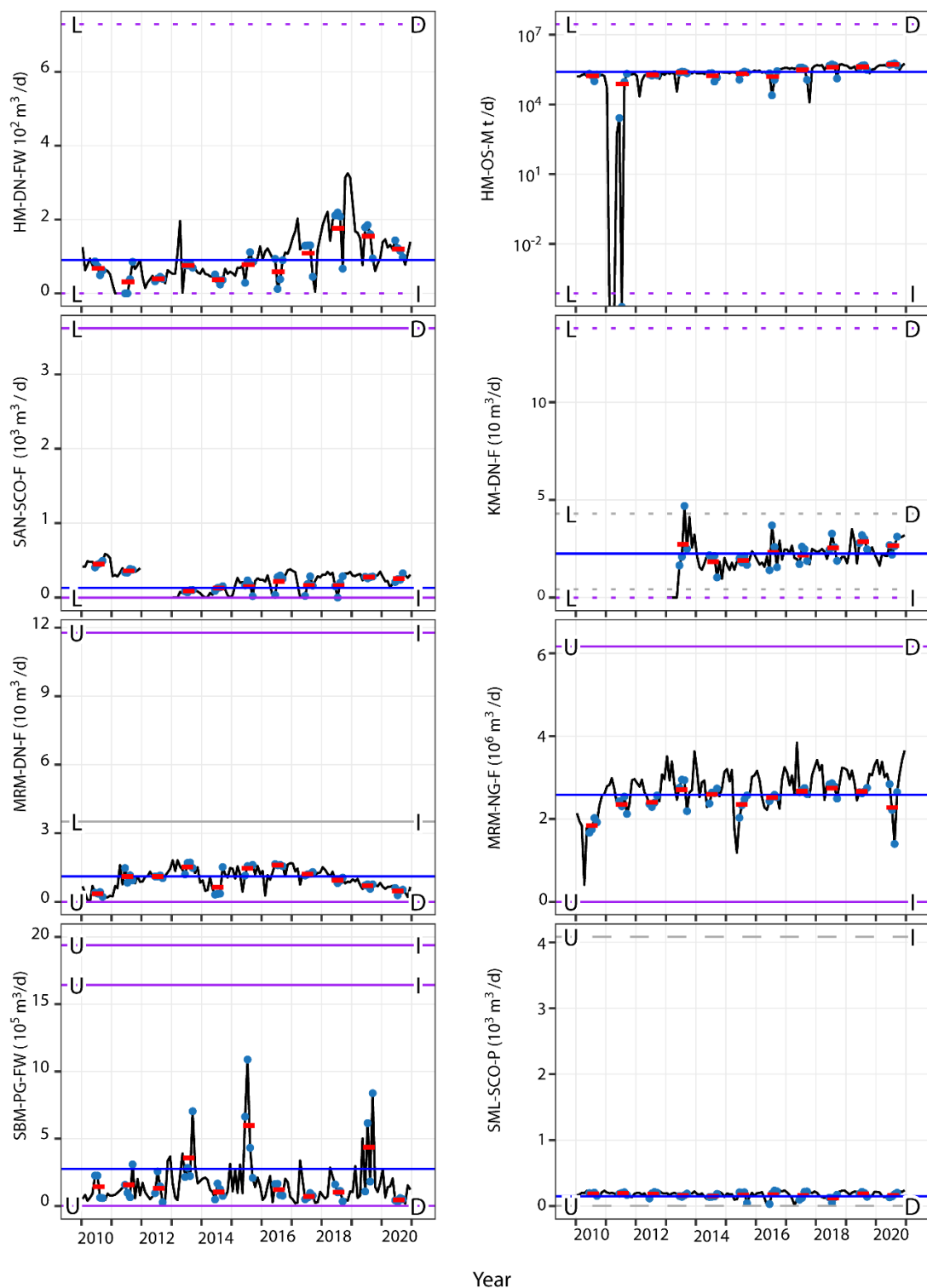
Supplemental Figure S17. AICs, MSEs, and Deviance ratios for model scenarios among male lake chub at the upper and lower locations; AIC=Akaike's Information Criterion; MSE=Mean Squared Error; blue values denote Deviance Ratios of regularized regression models; 'Fish' =models with no environmental or industrial covariates; 'ENV' includes environmental covariates only; IND includes industrial covariates only (with no limits and no penalty factors); ENV+IND with no limits and no penalty factors (NL-NPF); ENV+IND with no limits and penalty factors (NL-PF); ENV+IND with upper limits and no penalty factors (UL-NPF); ENV+IND with upper limits and penalty factors (UL-PF).



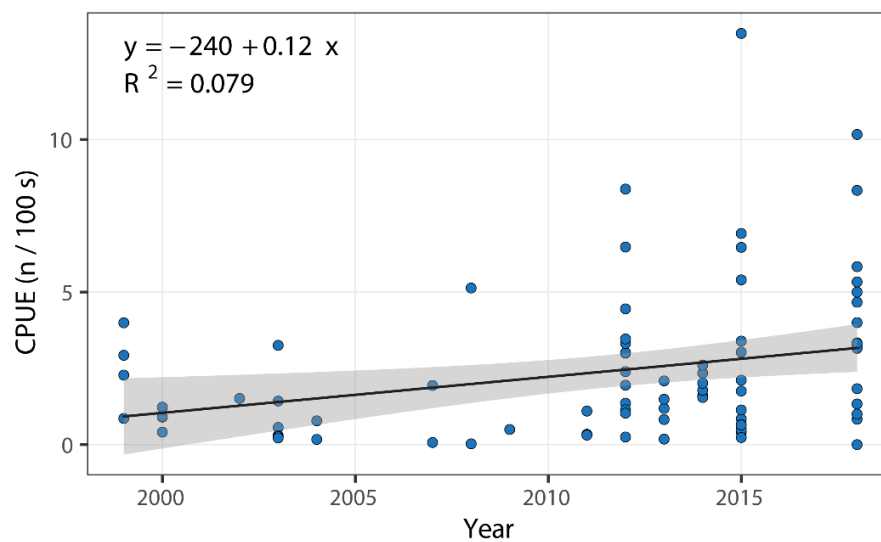
Supplemental Figure S18. Mean water temperature per day in 2013-2015 and 2018 at the Upper and Lower Ells fishing locations; diagonal black line is 1:1 line.



Supplemental Figure S19. Effect Size plots from zero (horizontal blue lines) with greater or lesser industrial activities; purple lines=females; dark gray=males; solid=gonad weight; dashed=liver weight; dotted=body weight; L=lower site; U=upper site; D=decrease in fish measurement; I=increase in fish measurement; black lines = monthly industrial values from 2010-2020; blue dots = June, July, August, September; Red lines = mean summer values for industrial endpoints.



Supplemental Figure S20. Effect Size plots from mean 2013-2015 and 2018 activity levels (horizontal blue lines) with greater or lesser industrial activities; purple lines=females; dark gray=males; solid=gonad weight; dashed=liver weight; dotted=body weight; L=lower site; U=upper site; D=decrease in fish measurement; I=increase in fish measurement; black lines = monthly industrial values from 2010-2020; blue dots = June, July, August, September; Red lines = mean summer values for industrial endpoints.



Supplemental Figure S21. Catch-per-unit-effort (CPUE; fish per 100 seconds of electrofishing) for sites in the Ells Basin (data obtained from the Alberta Fish and Wildlife Management Information System; FWMIS; <https://www.alberta.ca/access-fwmis-data.aspx>).