Supplemental Information

Controls on the epilimnetic phosphorus concentration in small temperate lakes

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S1. Regression tree analysis

The regression tree analysis was performed to provide a first estimate of the predictors and establish critical thresholds for the epilimnetic P concentrations in the multiple linear regression models. The analysis was performed with the full set of parameters on 96 lakes for which a complete dataset existed. This approach is particularly useful when several factors influence response at specific thresholds. It performs recursive dichotomous splits to explain the variation of a response variable by segmenting the predictor space into regions that minimize the residual sum of squares (De'ath and Fabricius, 2000). The predictor variables (Table 1) can be used repeatedly throughout the partitioning, allowing the reevaluation of the variables after the previous splits have been made (Quinn and Keough, 2002). Regression trees provide a mean value of the response variable for the group on each end of the split, in contrast to traditional regression that predicts an individual value for each observational value. Regression tree analysis was performed in R (R Core Team, 2015) using the package rpart (2015), v. 4.1-10 (Therneau et al., 2016). A cost complexity pruning algorithm was used to reduce the tree size to avoid overfitting the data in the regression tree without reducing predictive accuracy, as determined by a cross-validation set.

Figure S1 shows the results of the regression tree analysis. The values listed at each node are mean epilimnetic P concentrations. The predictor variables represent watershed (%Ag:WA), physical (Z_{avg}), and chemical (Al:P ratio and DOC) characteristics. Further, lakes that have a relatively high agricultural activity in their watershed, are relatively shallow, and have a relatively low sediment Al:P ratio are especially susceptible to eutrophication. The results of the regression tree analysis that include lake physiochemical and land-use drivers helped us to identify predictor variables used in the multiple linear regression model development.

Table S1. Lake water column, sediment chemistry, and land-use data.[a]

Midas[b]	Epi P	Hypo P	%Ag:WA	%AdjAg:LA	WA:LA	Road:WA	Al_{NaOH}:Fe_{BD}	Al_{NaOH}:P_{BD}	P_{BD}	Al_{NaOH}	Fe_{BD}	Z_{avg}	*Sch*	T_{hyp}	DOC	pH	OI
78 [c]	4	3.4	0.03	0.07	9.4	0.005	0.99	97.32	2.8	272.5	275.2	30.6	1719.5	6	2.7	7.1	7.4
177 [c]	5.2	4.6	1.59	1.14	3.9	0.005	0.73	37.40	3	112.2	153.9	7.7	6.5	22	4.4	6.7	0.9
224 [c]	1.9	2.6	0	0	4.7	0.009	0.84	38.78	5.8	224.9	268.5	37.7	2141	6.1	2	7	11.5
3444 [c]	3.5	4.9	5.27	13.1	7.2	0.01	1.05	65.75	5.7	374.8	356.0	24.7	880.6	7.8	3.2	7.2	3.2
3446 [c]	4.2	9.1	3.31	4.17	3.6	0.011	6.36	72.43	2.8	202.8	31.9	10	316.7	11.7	2.7	7.1	4.3
3748 [c]	6.1	20.7	9.24	16.2	5.5	0.01	1.30	7.82	15.4	120.5	92.8	24	866.8	7.6	2.6	7.4	4.3
3750 [c]	5.1	9.2	10.69	5.6	14.6	0.011	1.54	27.97	3.2	89.5	58.2	8.2	152.6	9.9	3.9	7.6	3.9
3796 [c]	19.2	NA	7.8	31.34	10.3	0.01	0.89	13.55	11.8	159.9	179.7	2.8	3	23	3.3	7.4	1.4
3838 [c]	5.5	9.1	6.48	4.76	29.7	0.014	0.26	6.82	42.3	288.3	1125.8	22.2	508.6	6	3.1	7.1	5.4
3916 [c]	4	13.2	1.64	1.76	5.2	0.014	0.81	21.49	7.4	159.0	196.6	7.3	100.1	11.1	2.4	7	3.8
4434 [c]	2.6	2.4	0.02	0.02	4.5	0.003	0.29	81.78	1.8	147.2	510.6	46.7	2785.3	4.9	2.5	6.4	7.7
4538 [c]	4.4	5.5	0.08	0	4.5	0.008	8.52	219.32	1.9	416.7	48.9	12.6	172.3	7.5	2.6	6.9	NA
5172 [c]	12.6	10.6	14.03	6.57	31.5	0.008	1.60	11.65	13.1	152.6	95.6	7.2	18.8	19.1	5.9	7.3	2
5190 [c]	3.3	4.3	0.96	0.86	5.1	0.008	4.97	123.50	3	370.5	74.6	23.6	1423.6	5.5	2	7.4	9.2
5272 [c]	5.3	53.3	2.56	1.27	59.8	0.007	2.14	32.28	9.7	313.1	146.3	24.2	577.7	5.4	3.4	7.1	8.5
5274 [c]	6.8	8.1	3.61	3.07	6.5	0.006	1.75	28.16	7.7	216.8	124.2	14.1	147.8	14.4	3.3	7	1.4
5280 [c]	7.5	19.6	8.6	7.31	39.1	0.008	0.36	3.95	82.5	325.8	903.4	24.8	477.5	6.8	3.8	7.1	2.8
5344 [c]	19	15.3	7.99	6.63	8.4	0.009	2.67	63.43	2.8	177.6	66.5	2.5	4.6	23.1	3.2	7.2	1.6
5348 [c]	9.3	NA	2.63	3.24	6	0.012	2.52	47.37	5.4	255.8	101.5	4.7	0.2	23.8	3.4	7.7	3.8
5349 [c]	12.6	NA	1.25	0.97	2.8	0.012	1.82	24.45	6.2	151.6	83.2	3.8	31.6	23.6	3	7.3	2
5352 [c]	10.7	23.7	5.68	6.74	10.8	0.017	1.02	5.59	25.2	140.8	137.8	8.6	197.6	10.9	3.2	7.8	5.6
5400 [c]	7.5	14.2	8.58	22.36	18.7	0.01	2.89	76.46	5	382.3	132.4	25.9	513.5	8	3.5	6.9	6.1
5408 [c]	21	280	11.69	25.55	5.5	0.01	0.61	3.26	46.7	152.4	248.2	8.1	90.2	11.7	3.8	8.2	2.4
5448 [c]	13.9	33.3	10.51	27.13	12	0.008	0.41	1.63	53.1	86.6	210.4	16.7	439.7	8.8	3.9	8.9	3.8
70 [c]	9	NA	12.69	14.74	8.2	0.01	1.37	51.15	6.1	312.0	228.0	3	8.1	23.9	4.2	7.3	1.9
80	13	NA	NA	NA	NA	0.007	1.80	54.15	4.1	222.0	123.3	NA	NA	22.7	7	7.2	NA
121	6	14	NA	NA	101.5	0	5.01	154	2	308.0	61.5	10.6	17.9	14.3	4.4	7.1	2.1
243 [c]	4	NA	0	0	8.6	0.002	2.67	9080	0.05	454.0	170.0	12.8	210.3	10.7	3.8	6.8	3.7

Midas[b]	Epi P	Hypo P	%Ag:WA	%AdjAg:LA	WA:LA	Road:WA	Al_{NaOH}:Fe_{BD}	Al_{NaOH}:P_{BD}	P_{BD}	Al_{NaOH}	Fe_{BD}	Z_{avg}	*Sch*	T_{hyp}	DOC	pH	OI
262 [c]	9	NA	0	0	20.9	0.008	9.26	225.33	3	676.0	73.0	13.4	122.1	10.8	3.5	7	5.2
342 [c]	3	NA	0	0	15.3	0.007	2.45	67.65	5.1	345.0	141.0	22.1	401.4	6.1	3.2	6.9	4.8
386	15	42	0	0	11	0.018	2.93	148.64	2.2	327.0	111.6	5	4.3	12.7	3.2	NA	6
410	10	NA	0	0	NA	0	0.74	54.74	3.8	208.0	279.4	NA	NA	19.1	3.7	7	NA
447	7	NA	0	0	443.6	0	3.84	72.35	1.7	123.0	32.0	1.1	0.2	19.4	5.1	6.7	NA
760	10	NA	4.94	6.75	9.6	0.012	1.74	14.75	8	118.0	68.0	3.3	0	22.7	4	7.6	NA
954 [c]	4	NA	0.15	0	9.3	0.003	2.56	225.63	1.6	361.0	141.0	22.5	61.3	14.6	5.2	6.6	1.4
1068 [c]	6	NA	4	2.12	8.8	0.012	2.35	93.85	1.3	122.0	52.0	3.7	2.3	21.6	2.9	7	3.2
1070	5	NA	NA	NA	5.6	0.003	1.07	46.71	8.2	383.0	358.8	29.3	280.9	10.5	3.8	6.9	1.4
1078 [c]	9	NA	0.04	0	12.1	0	1.61	241.11	0.9	217.0	134.5	3.8	2.3	22.5	5.8	6.6	0.8
1088 [c]	8	NA	0.11	0	15.9	0.002	4.08	7840.00	0.05	392.0	96.0	12.8	231.1	9.3	4.6	6.9	4
1150 [c]	4	NA	0	0	10.1	0.001	0.57	62.41	2.9	181.0	318.3	27.4	136.6	12.4	3.1	6.9	1.7
1210 [c]	6	10	0.05	0	11.1	0.002	1.74	85.69	6.5	557.0	321.0	11.9	26	13.3	4.6	6.5	2.6
2004 [c]	5	NA	0	0	5	0.006	11.68	630.71	1.4	883.0	75.6	3.2	5.5	20.5	3.5	6.9	3.3
2020 [c]	5	NA	0	0	138.1	0.003	0.65	53.13	3.2	170.0	260.1	19.6	174.6	11.2	3.8	7	1.4
2146 [c]	6	NA	0.53	0.82	25.8	0.007	2.05	100.00	1.8	180.0	88.0	11.3	135.2	11.5	3.7	6.9	4
2156 [c]	15	NA	19.64	15.95	19.8	0.009	1.73	19.66	5.8	114.0	66.0	2.9	1.6	22.8	6.3	7.6	2.8
2242 [c]	5	NA	1.91	7.21	7.5	0.012	5.21	22.73	6.6	150.0	28.8	5.1	17.6	17.6	3.4	7.6	3.2
2286 [c]	33	NA	7.47	23.22	134.9	0.007	0.97	10.72	13.8	148.0	152.0	2.7	8.7	22	6.7	9.1	2.6
2590 [c]	7	12	4.26	5.96	36.4	0.007	2.22	54.34	5.3	288.0	130.0	10.8	50.5	13.2	4.8	7.3	1.3
2608 [c]	6	17	1.65	0.1	12.9	0.006	3.99	74.04	8.9	659.0	165.0	13.4	258.4	8.8	3.4	7.4	7.5
2948 [c]	5	NA	0	0	10.8	0	0.71	45.66	5.3	242.0	342.0	24.5	223.1	9.1	6	7	2.4
3038 [c]	7	NA	2.14	1.99	20.7	0.003	3.83	400.00	0.4	160.0	41.8	7.8	1.7	21.7	6.4	7.1	2.3
3376	14	NA	0.93	0.29	15	0.01	7.51	43.26	4.6	199.0	26.5	7.4	77.9	6.1	4.2	NA	11.9
3388 [c]	6	NA	3.61	14.77	7.8	0.016	2.56	66.76	3.4	227.0	88.5	3.5	0.7	23	3.2	7.1	4.2
3434 [c]	9	14	9.41	18.29	15	0.015	4.27	59.20	8.8	521.0	122.0	9.3	105.2	12.5	3.3	7.6	3.2
3452 [c]	6	NA	6.58	17.48	14.1	0.01	2.78	193.79	2.9	562.0	202.0	10.3	519.4	8.4	4.4	7	8.2
3454 [c]	6	14	3.41	8.5	9.6	0.011	7.27	10240	0.05	512.0	70.4	4.97	54.4	11.7	3.2	6.6	2.8
3604	5	9	3.67	25.16	16	0.007	3.25	92.76	2.9	269.0	82.8	8.5	260.2	10.1	3.5	NA	5.8

Midas[b]	Epi P	Hypo P	%Ag:WA	%AdjAg:LA	WA:LA	Road:WA	Al_{NaOH}:Fe_{BD}	Al_{NaOH}:P_{BD}	P_{BD}	Al_{NaOH}	Fe_{BD}	Z_{avg}	*Sch*	T_{hyp}	DOC	pH	OI
3626[c]	8	16	2.26	0	10.4	0.026	3.03	27.10	13.1	355.0	117.0	7.5	152.2	5.8	3.7	7.9	14.6
3672[c]	7	9	0.61	10.85	22.9	0.003	2.05	170	1.9	323.0	157.7	5.4	166.6	12.1	3.1	7.1	2.9
3682[c]	6	NA	2.37	17.36	31.1	0.005	1.32	326.92	1.3	425.0	321.4	18.8	527.1	5.1	2.4	7	6
3690[c]	7	13	2.63	0.48	9.7	0.01	4.37	33.89	10.8	366.0	83.8	8.2	56.6	10.4	2.8	7.3	4.8
3780[c]	8	NA	1.78	4.89	4.5	0.012	8.00	127.41	2.7	344.0	43.0	5.4	8.3	14.9	3.6	6.8	8.4
3814[c]	16	82	13.07	47.42	5.5	0.016	2.02	20.00	11.4	228.0	113.1	3.2	38.3	16.3	3.5	7.8	5
3830[c]	7	42	5.9	9.29	54.1	0.008	1.99	26.29	14.3	376.0	189.0	5.1	14.3	13.5	4.1	7.5	5.3
3884[c]	13	NA	9.99	44.05	5	0.015	0.91	13.98	12.8	179.0	197.0	3.3	2.9	21.2	4.8	7	7.2
3920	10	11	NA	NA	6	0.012	4.81	53.04	6.3	334.2	69.4	8.1	603.6	10.2	2.5	7.1	4.5
4272[c]	5	10	0.63	2.71	16.7	0.007	2.77	199.13	2.3	458.0	165.1	3.9	63.3	11.9	3.9	6.8	7.1
4316[c]	11	30	5.42	3.45	90.1	0.007	1.95	64.44	4.5	290.0	149.0	5.1	24.5	15	3.6	7	5.8
4322[c]	5	12	0.55	2.16	9.3	0.009	5.63	154.86	3.5	542.0	96.3	10.4	130.6	8.1	2.8	6.8	7.5
4328[c]	3	NA	1.87	2.21	6.6	0.007	1.25	211.20	2.5	528.0	422.0	27.8	459.7	10.5	2.6	6.9	3.2
4330[c]	10	NA	0.9	3.8	9	0.007	4.84	137.59	2.9	399.0	82.4	2.1	2.4	22.8	3	6.8	4.6
4336[c]	9	NA	2.4	6.45	64.7	0.008	2.78	88.33	3	265.0	95.3	4.2	7.3	22.8	3.8	6.9	2.7
4388[c]	7	12	0.79	6.09	9.2	0.008	7.06	4800	0.05	240.0	34.0	6.4	32.5	13.7	4.7	6.7	3
4452[c]	3	NA	0	0	15.3	0.016	6.09	15720	0.05	786.0	129.0	7.2	3.5	17.4	2.5	6.8	20.4
4492	5	7	0	0	10.8	0.007	4.79	177.22	1.8	319.0	66.6	11.1	77	13.4	4	6.7	4.9
4606[c]	2	NA	0	0	5.3	0.012	3.20	10620	0.05	531.0	166.0	21	306.6	10.4	1.8	6.7	10.1
4608[c]	2	NA	0	0	6.7	0.004	0.53	9020	0.05	451.0	843.8	21.6	1392.1	6	1.7	6.8	29.6
4610[c]	4	11	0	0	33	0.028	10.32	16100	0.05	805.0	78.0	8.1	51.8	7.8	4.1	6.5	13.9
4612[c]	4	6	0	0	21.8	0.008	13.08	16480	0.05	824.0	63.0	8.3	16.8	10	4.5	6.5	10.1
4614	5	24	0	0	62.7	0.016	5.02	85.52	2.9	248.0	49.4	5	5.7	12	5.5	6.4	5.9
4618[c]	12	NA	0	0	12.4	0.014	4.81	52.35	3.4	178.0	37.0	3.2	5.1	13.8	7.5	6.6	12.1
4620[c]	7	NA	0	0	6.6	0.006	4.47	85.36	2.8	239.0	53.5	3.2	2.1	19.3	5	6.2	8.7
4622[c]	2	NA	0	0	0.5	0.01	0.28	747.50	0.4	299.0	1064.2	30.2	69.8	10	2.9	6.6	0.9
4624[c]	4	6	0	0	6.5	0.019	6.58	7500	0.05	375.0	57.0	13.6	79.6	11.6	2.8	6.9	7.8
4628[c]	8	NA	0	0	20.2	0.044	8.30	9460	0.05	473.0	57.0	3.9	4.3	18.6	8.1	6.3	9
4630[c]	3	8	0	0	12.5	0.01	4.83	11760	0.05	588.0	121.7	9.7	13.5	13.9	4.3	6.7	4.8

Midas[b]	Epi P	Hypo P	%Ag:WA	%AdjAg:LA	WA:LA	Road:WA	Al_{NaOH}:Fe_{BD}	Al_{NaOH}:P_{BD}	P_{BD}	Al_{NaOH}	Fe_{BD}	Z_{avg}	*Sch*	T_{hyp}	DOC	pH	OI
4766[c]	8	NA	0.18	0	9.4	0.003	2.49	135.63	3.2	434.0	174.0	13.1	4.1	19.1	6.1	6.7	1.1
4782	8	NA	0.08	0	6.9	0.004	8.95	8180	0.05	409.0	45.7	1.2	0.4	20.1	7	6.4	NA
4788	6	NA	0	0	4.7	0.004	5.82	212.50	0.8	170.0	29.2	4.8	0.2	22	3.8	NA	NA
4800[c]	6	13	10.19	26.29	35.7	0.025	2.67	75.26	7.6	572.0	214.0	5.4	34.6	15.1	3.2	7	6
4802	11	NA	0	0	21.7	0.01	7.77	4460	0.05	223.0	28.7	2.5	0.1	23.3	3.9	NA	3
4806[c]	17	NA	9.7	62.43	7.9	0.014	3.74	113.33	2.4	272.0	72.8	3.2	0	23.5	2.4	6.8	3.7
4822[c]	13	57	9.89	33.02	7.7	0.021	1.22	11.78	16.3	192.0	157.7	4.3	62.6	13.8	2.5	7.5	5.8
4852[c]	6	NA	7.18	20.97	15.1	0.016	0.51	8.32	11.3	94.0	183.9	13.7	140.9	8.8	2.7	6.9	3.2
4857[c]	9	15	1.65	11.9	8.2	0.009	3.91	100.00	2.9	290.0	74.2	5.7	24.2	10.7	5.3	6.3	4.9
4894[c]	6	NA	2.39	5.8	5.1	0.019	5.16	215.63	1.6	345.0	66.9	7	5.5	22.1	3	6.8	3.3
4896[c]	6	NA	2.9	5.66	24.4	0.01	0.95	39.50	10.1	399.0	421.0	27	1033.9	5.7	4.3	7.1	6.4
5024[c]	5	22	3.14	12.6	8.3	0.444	2.16	54.77	4.4	241.0	111.8	16.1	276.7	5.2	2.5	7.1	5.5
5174[c]	16	NA	7.38	9.58	12.3	0.013	2.77	66.82	2.2	147.0	53.0	2.8	0.3	22.4	4.5	7.2	1.2
5198[c]	12	NA	17.74	4.75	14	0.015	2.17	34.21	11.4	390.0	180.0	2.4	7.1	23.1	3.7	7.2	6.6
5222[c]	10	22	3.33	40.36	30.7	0.009	3.90	145.36	2.8	407.0	104.3	11.9	262.4	8.4	3.9	6.6	6.3
5236[c]	12	24.5	15.35	19.12	15.8	0.01	0.66	3.58	62.6	224.0	341.0	23.7	247.3	9.8	3.5	7.9	1.7
5240[c]	8	17	5.75	12.73	21.3	0.015	2.21	32.38	10.5	340.0	154.0	13.9	155.8	6.5	3.1	7.6	4.4
5386[c]	12	NA	8.21	19.77	31.9	0.009	3.43	96.08	5.1	490.0	143.0	2.6	12.9	22.7	4.7	7.2	2.8
5416[c]	35	55	7.82	2.16	14.9	0.011	0.75	3.79	31.4	119.0	159.0	6.9	14.8	16.9	4	8.4	2.5
5458[c]	12	NA	4.07	15.71	20.8	0.008	1.29	16.06	13.2	212.0	164.0	4.2	30.8	20.1	5.4	8	3.5
5490[c]	8	9	1.71	0	6.8	0.006	5.03	257.86	1.4	361.0	71.7	4.8	24.9	13.2	3.5	6.8	4.9
5682[c]	13	24.5	10.73	75.28	136	0.009	2.39	60.56	5.4	327.0	137.0	12.4	150.2	11.4	5.1	7.3	4.1
5690[c]	15	33	15.73	91.7	37.9	0.012	2.59	37.71	10.9	411.0	158.8	7.2	87.2	12.3	5	6.9	5.7
5710[c]	7	NA	1.75	6.31	50	0.012	7.49	153.18	2.2	337.0	45.0	9	355	9.8	4.5	6.7	8.8
5780[c]	7	7	5.18	8.93	14.2	0.01	3.28	324.38	1.6	519.0	158.0	10.8	133	12.2	3.5	6.9	1.8
5814[c]	5	NA	2.78	3.09	25.7	0.011	1.01	21.58	15.2	328.0	325.4	29.3	272.5	5.7	3.4	7	3.6
9685	5	8	2.31	6.08	105.2	0.014	5.90	2690	0.1	269.0	45.6	8.9	46.6	13.5	3.6	NA	3.2
9931[c]	18	NA	1.91	2.74	8.5	0.014	1.06	4.22	45	190.0	180.0	9.9	75.9	13.1	3	7.4	3.7
3130	9	13	5.35	11.41	6.4	0.016	4.83	121.57	3	364.7	75.5	9	120.8	9.2	NA	6.7	5.5

Midas[b]	**Epi P**	**Hypo P**	**%Ag:WA**	**%AdjAg:LA**	**WA:LA**	**Road:WA**	**Al_{NaOH}:Fe_{BD}**	**Al_{NaOH}:P_{BD}**	**P_{BD}**	**Al_{NaOH}**	**Fe_{BD}**	**Z_{avg}**	***Sch***	**T_{hyp}**	**DOC**	**pH**	**OI**
3382	4	17	1.45	0	3.1	0.015	4.78	71.72	2.5	179.3	37.5	7.5	422.6	9.7	NA	6.6	9.8
3424	7	12.5	10.18	22.62	17.3	0.01	9.19	121.59	2.2	267.5	29.1	6.6	138.8	9.1	NA	6.9	8.9
3199	5	10.5	0.54	4.63	35.9	0.009	2.26	105.55	3.1	327.2	144.9	5.9	106.6	7.5	NA	6.8	13.7
3420	11	21	6.18	17.87	7.4	0.012	5.16	96.60	5.8	560.3	108.5	12.1	437.8	5	NA	6.8	11
5582	9	10	4.7	36.7	24.5	0.016	8.29	102.62	3.9	400.2	48.3	7.4	119.9	7.8	NA	6.7	8.1
3132	4	18	0.73	0	4.1	0.011	3.15	101.56	2.5	253.9	80.6	13	172.7	8	NA	6.7	3.5
3126	8	8.5	3.61	12.53	8.2	0.016	6.33	55.70	5.6	311.9	49.3	5.1	15.1	15.8	NA	6.6	6.4
3234	7	14	1.45	4.85	13.3	0.012	4.69	87.69	5.2	456.0	97.3	6.6	238.4	7.1	NA	6.6	8.7
3448	9	13.5	3.86	60.13	16.9	0.008	11.03	156.54	2.6	407.0	36.9	11.1	114.3	8.1	NA	6.7	7
3232	6	12.5	2.78	17.75	13.9	0.012	6.81	140.11	3.5	490.4	72.0	7.7	125.6	9.1	NA	6.6	7.1
3456	12	7.7	1.83	3.88	8.4	0.008	3.70	284.96	2.5	712.4	192.6	3.9	70.6	16.7	NA	6.6	4.3
n	126	70	122	122	124	126	126	126	126	126	126	126	124	126	114	120	119
Range	1.9-35	2.4-280	0-19.64	0-91.7	0.5-443.6	0-0.444	0.26-13.08	1.63-16480	0.05-82.5	86.6-883	26.5-1126	1.1-46.7	0-2785	4.9-23.9	1.7-8.1	6.2-9.1	0.8-29.6
Mean	8.3	20.6	3.8	99	23.5	0.013	3.5	1230	7.3	326	162	11.0	216	13.4	3.9	7.0	5.4
Median	7	13	2.3	4.0	11.1	0.010	2.7	79.1	3.2	312	115	8.1	77.5	12.0	3.6	7.0	4.4

[a] EpiP (µg L^{-1}): epilimnetic P; hypoP: hypolimnetic P; Ag:WA: %agricultural area:watershed area; AdjAg:LA: %lake adjacent agricultural area:lake surface area; WA:LA: watershed area:lake surface area ratio; Ag:LA: agricultural area:lake surface area ratio; Road:WA: road surface area:watershed area ratio; Al:Fe: sediment $Al_{BD+NaOH}$:Fe_{BD} molar ratio; Al:P: sediment $Al_{BD+NaOH}$:P_{BD} molar ratio; P_{BD} (µmol g^{-1}): sediment P extracted by bicarbonate-dithionite; Al_{NaOH} (µmol g^{-1}): sediment Al extracted by bicarbo`nate-dithionite and NaOH; Fe_{BD} (µmol g^{-1}): sediment Fe extracted by bicarbonate-dithionite; Z_{avg} (m): area-averaged lake depth; *Sch* (J m^{-2}): Schmidt Stability; T_{hyp} (^{o}C): hypolimnetic temperature 1 m above lake bed; DOC (mg L^{-1}): dissolved organic carbon; OI: Osgood Index.

[b] Maine lake identifier accessed at http://www.lakesofmaine.org/your-lake.html.

[c] These lakes were included in predictive regression modeling.

Table S2. Hypolimnetic DO, Climate/weather, location, and elevation data.[a]

Midas[b]	DO_{hyp} (mg L^{-1})	T_{epi}	Max. Precip. January	Average Precip. January	Sum Precip. January	Max. Precip. May	Average Precip. May	Sum Precip. May	Degree-Day May	Latitude	Longitude	Elevation[c] (m)
78	9.6	22.4	33	2.61	618	33	3.36	393	1943	44.93002	-69.94942	126
177	8.6	19.3	62	3.01	679	62	2.97	315	1751	45.07812	-69.39989	53
224	5.1	22.9	50	2.75	651	50	3.70	433	1980	45.25447	-69.92649	386
3444	1.8	23.1	46	2.66	596	31	3.10	322	1823	44.08828	-70.49226	99
3446	9.7	19.6	45	2.81	651	32	3.46	387	1993	44.02313	-70.5189	130
3748	8.6	21.2	50	2.71	646	32	2.93	349	2176	44.15484	-70.24572	79
3750	4.3	25.3	50	2.57	596	30	2.78	311	2014	44.10937	-70.27902	73
3796	8.3	22	53	2.65	593	31	2.79	290	1820	44.15569	-70.10254	74
3838	2.1	21.6	49	2.85	671	41	3.12	362	2135	43.51829	-70.86478	143
3916	4.8	20.7	50	2.93	691	43	3.25	376	2113	43.5673	-70.88877	159
4434	10.9	19.3	65	3.05	689	65	3.22	341	1719	44.59309	-68.06811	63
4538	8.2	22.1	27	2.44	580	27	2.58	304	2032	44.78949	-68.45292	112
5172	0.2	23.1	28	2.42	539	28	2.65	272	1756	44.63267	-69.33733	53
5190	8.9	22.7	40	2.77	637	40	3.49	384	1785	44.72568	-70.08022	171
5272	0.2	24	43	2.53	583	43	2.91	322	1929	44.53087	-69.86854	72
5274	3.5	23.1	53	2.52	581	53	2.90	322	1901	44.54562	-69.85496	75
5280	0.2	20.9	39	2.51	565	31	2.86	300	1795	44.48882	-69.78232	71
5344	8.5	21	34	2.55	574	29	3.04	319	1772	44.62965	-69.83641	77
5348	5.3	22.4	38	2.44	544	38	2.77	285	1733	44.56619	-69.76167	84
5349	8.3	20.8	35	2.50	574	34	2.86	314	1891	44.61267	-69.77957	80
5352	0.2	21.4	39	2.60	585	39	3.09	324	1769	44.5206	-69.78636	84
5400	7	25.9	44	2.67	641	34	2.51	301	2117	44.17599	-69.47588	16
5408	1.2	20.1	44	2.41	534	30	2.34	239	1751	44.40474	-69.65847	36
5448	4.8	19.5	39	2.40	533	29	2.29	233	1745	44.43288	-69.56964	59
70	7.1	25.6	47	2.98	659	30	2.74	276	1697	44.82877	-69.76435	102
80	8	23	61	3.56	841	40	3.77	437	2007	44.93207	-68.79489	35

Midas[b]	DO_{hyp} (mg L^{-1})	T_{epi}	Max. Precip. January	Average Precip. January	Sum Precip. January	Max. Precip. May	Average Precip. May	Sum Precip. May	Degree-Day May	Latitude	Longitude	Elevation[c] (m)
121	0.2	22.4	38	3.54	836	28	3.88	449	1889	45.66648	-67.70291	129
243	4.5	21.7	79	3.89	948	79	4.20	520	2089	45.59662	-68.95802	160
262	0.7	21.7	52	2.97	718	50	2.71	331	2050	45.10805	-69.65791	282
342	7.6	20.6	60	3.89	948	60	4.78	592	1963	45.47348	-69.52521	342
386	0.4	21.6	44	3.73	876	41	4.43	509	1792	45.47587	-69.55603	380
410	7.3	19.9	63	4.06	991	63	5.02	622	1954	45.49611	-69.49409	342
447	8.5	19.7	89	3.65	975	57	4.29	626	2604	44.29894	-68.25668	2
760	7.8	21.6	45	2.66	642	28	2.33	283	2109	45.12637	-69.2994	153
954	3.3	21.9	41	2.73	642	41	2.46	283	2029	45.46331	-68.88313	133
1068	8.9	21.6	31	3.33	785	30	3.48	403	1893	45.74734	-67.85553	136
1070	5.6	20.9	35	3.35	791	33	3.54	410	1888	45.67799	-67.80356	132
1078	7.6	23.4	49	3.58	837	49	3.80	433	1878	45.50793	-67.8354	127
1088	4.4	23.4	44	3.54	828	32	3.50	399	1887	45.40693	-67.79702	112
1150	4.3	17.4	52	2.82	748	42	2.76	402	2565	45.23427	-67.79879	94
1210	0.5	21.9	57	2.64	626	32	2.17	253	2036	44.8574	-67.9828	97
2004	2.8	22.5	40	2.74	645	40	2.47	284	2027	45.52415	-68.8066	151
2020	0.6	23.3	59	3.64	825	31	3.81	407	1775	45.77675	-68.81272	121
2146	2.3	23.5	54	3.35	768	32	3.34	364	1819	45.28556	-68.52398	58
2156	8.7	23.6	56	3.37	795	43	3.52	408	2001	45.01694	-68.93648	44
2242	1	23.3	46	3.48	797	32	3.61	393	1813	45.34826	-68.31377	121
2286	3.7	25.2	43	2.48	606	23	2.12	264	2370	44.78071	-68.93905	37
2590	0.3	23.1	48	2.52	609	22	2.10	255	2185	44.91318	-69.54601	75
2608	0.6	23.5	45	2.78	673	20	2.29	279	2201	44.77748	-69.5846	70
2948	3.6	21.7	29	2.25	545	28	2.34	285	2000	45.86571	-69.54524	294
3038	7	22.2	44	3.51	829	32	3.73	432	1919	45.65983	-68.30424	108
3376	0.4	23.3	69	3.31	784	41	2.68	313	2105	43.93071	-70.65781	155
3388	7.5	23.3	100	3.73	931	35	2.90	377	2402	43.99273	-70.51502	130
3434	0.3	27.2	85	3.57	871	50	3.04	377	2269	44.21469	-70.57212	121

Midas[b]	DO_{hyp} (mg L^{-1})	T_{epi}	Max. Precip. January	Average Precip. January	Sum Precip. January	Max. Precip. May	Average Precip. May	Sum Precip. May	Degree-Day May	Latitude	Longitude	Elevation[c] (m)
3452	0.6	26.7	81	3.77	916	61	3.35	411	2195	44.12538	-70.67132	95
3454	0.1	22.8	63	3.51	799	39	2.96	319	1905	44.0705	-70.73411	129
3604	0.5	24.1	61	3.46	796	35	3.14	345	1887	44.42017	-70.32136	122
3626	0.4	25.4	88	3.51	856	32	2.87	356	2324	44.28232	-70.269	100
3672	0.3	23.8	54	3.45	765	31	3.47	354	1681	44.695	-70.45172	207
3682	5	24	55	3.40	754	32	3.28	334	1708	44.59583	-70.24938	174
3690	0.3	25.4	88	3.53	857	33	2.71	333	2275	43.96946	-70.42401	93
3780	0.5	25	62	3.45	762	31	2.97	300	1597	44.21894	-70.45704	255
3814	0.2	23.4	62	3.44	807	36	2.96	339	2056	44.23103	-70.04435	82
3830	0.2	22.6	63	3.24	812	59	2.67	349	2403	44.3202	-70.02988	74
3884	1.1	22.7	99	4.22	1054	79	3.07	399	2548	43.25595	-70.76232	31
3920	0.3	25	91	4.09	941	32	2.75	302	2081	43.55762	-70.9362	175
4272	0.3	23.5	45	3.28	722	34	3.20	320	1664	44.81475	-68.49757	78
4316	0.2	24	52	2.79	637	21	2.35	255	2019	44.65675	-68.68365	19
4322	0.7	23.6	52	2.79	638	20	2.32	252	2013	44.6447	-68.74536	62
4328	6.1	23.4	61	2.76	632	22	2.25	245	1973	44.61419	-68.57198	73
4330	8.2	23.8	59	2.80	642	22	2.31	252	1980	44.58874	-68.5967	95
4336	6.9	24.3	57	2.91	666	22	2.46	267	1991	44.57581	-68.69672	6
4388	0.2	23.2	35	3.13	709	35	2.67	285	1763	44.55192	-68.13376	37
4452	8.9	17.9	102	3.84	1013	57	4.54	649	2499	44.3443	-68.23855	102
4492	0.8	22.1	54	2.54	602	24	2.11	247	2033	44.89641	-68.22517	102
4606	3.8	19.4	102	3.84	1009	57	4.55	645	2485	44.35513	-68.25176	84
4608	10.1	18.4	89	3.67	964	57	4.34	615	2546	44.33324	-68.25525	83
4610	8.4	18.7	89	3.67	968	57	4.33	619	2560	44.3099	-68.28992	58
4612	0.1	18.7	89	3.67	968	57	4.33	619	2560	44.32108	-68.28691	70
4614	0.1	19.6	84	3.45	899	46	4.14	579	2426	44.35924	-68.34562	12
4618	8.6	19.7	84	3.46	912	46	4.14	592	2469	44.36727	-68.36428	21
4620	0.2	18.4	84	3.45	899	46	4.14	579	2426	44.35327	-68.37781	23

Midas[b]	DO_{hyp} (mg L^{-1})	T_{epi}	Max. Precip. January	Average Precip. January	Sum Precip. January	Max. Precip. May	Average Precip. May	Sum Precip. May	Degree-Day May	Latitude	Longitude	Elevation[c] (m)
4622	7	20.5	83	3.40	894	45	4.05	22.35	2482	44.31439	-68.35458	19
4624	0.6	19.9	84	3.52	919	53	4.21	574	2474	44.32178	-68.3358	26
4628	7.7	20.1	79	3.35	873	45	3.98	588	2455	44.32342	-68.39736	12
4630	0.1	20.1	79	3.35	873	45	3.98	557	2455	44.30321	-68.39634	12
4766	0.4	21.5	53	2.45	579	25	1.96	557	2075	45.05844	-68.13756	107
4782	7.9	20.9	42	3.44	862	42	3.50	228	2215	45.10444	-68.0724	108
4788	8.4	22.1	55	2.58	611	29	2.10	458	2053	45.02014	-68.06924	137
4800	0.2	26.2	70	4.15	1011	70	3.04	245	2277	44.21615	-69.21109	81
4802	7.5	23.4	75	3.71	823	32	2.79	376	1717	44.22625	-69.1852	106
4806	7.1	23.6	75	3.71	823	32	2.79	284	1717	44.24334	-69.17352	108
4822	0.4	23	76	3.72	829	34	2.68	284	1674	44.14192	-69.11361	37
4852	1.4	23	73	3.66	815	33	2.71	276	1709	44.24426	-69.11061	43
4857	0.2	22.7	64	3.56	841	57	2.79	279	1995	43.98933	-69.4476	17
4894	7.1	23	67	3.55	812	32	3.12	323	1888	44.29221	-69.36783	98
4896	0.6	24.5	60	3.47	842	32	2.70	340	2273	44.35873	-69.43467	86
5024	0.6	23	59	4.14	1004	55	3.94	332	2148	43.59641	-70.70685	95
5174	6.1	23	62	3.37	752	29	2.92	484	1782	44.51508	-69.30497	140
5198	3.7	25	39	3.08	707	39	2.36	300	1935	44.59711	-70.1764	115
5222	1.4	22.5	80	3.62	900	36	3.08	259	2268	43.95073	-69.77071	0
5236	0.1	26.2	64	3.22	744	35	2.58	397	2066	44.25087	-69.94375	50
5240	0.2	26.1	68	3.42	837	37	2.85	285	2346	44.19493	-69.95101	53
5386	6	28.1	65	3.57	870	34	2.77	356	2293	44.18584	-69.52181	39
5416	0.2	22.2	60	3.27	778	30	2.64	343	2169	44.36676	-69.60731	55
5458	1.9	25.4	48	2.93	718	27	2.53	311	2324	44.5313	-69.56234	43
5490	0.2	25.5	56	3.51	796	30	3.06	316	1831	44.54176	-69.05426	87
5682	0.2	27.6	64	3.92	956	50	2.96	327	2291	44.25629	-69.26632	26
5690	0.2	22.5	73	3.75	858	32	3.15	367	1854	44.13116	-69.287	10
5710	2.6	23.8	75	3.51	804	34	3.06	343	1861	44.01432	-69.46965	23

Midas[b]	DO_{hyp} (mg L^{-1})	T_{epi}	Max. Precip. January	Average Precip. January	Sum Precip. January	Max. Precip. May	Average Precip. May	Sum Precip. May	Degree-Day May	Latitude	Longitude	Elevation[c] (m)
5780	1.3	23.8	78	3.74	906	78	3.50	426	2190	44.08275	-70.68175	82
5814	5.2	23.2	62	3.56	818	32	3.35	367	1894	44.43398	-70.03114	97
9685	0.2	22.8	69	3.39	772	40	2.73	294	1936	43.9548	-70.5901	82
9931	0.2	24.1	64	3.25	790	35	2.54	312	2289	44.32389	-69.65798	55
3130	NA	NA	30	2.94	584	30	4.34	343	1322	43.95325	-70.76694	153
3382	NA	NA	28	2.86	543	28	4.40	307	1147	43.93469	-70.60722	108
3424	NA	NA	28	2.90	533	28	4.54	290	963	44.13481	-70.73528	166
3199	NA	NA	35	3.24	624	35	5.29	385	1166	44.21000	-70.81417	174
3420	NA	NA	28	2.91	576	28	4.27	333	1274	44.15308	-70.71778	114
5582	NA	NA	59	3.41	812	59	4.90	577	2052	44.06584	-70.77170	146
3132	NA	NA	31	2.98	593	31	4.45	351	1313	43.94147	-70.74667	153
3126	NA	NA	30	2.94	584	30	4.34	343	1322	43.95422	-70.78556	160
3234	NA	NA	31	2.84	516	29	4.46	276	926	44.11925	-70.77667	134
3448	NA	NA	45	3.18	678	45	4.67	434	1609	44.15933	-70.64250	136
3232	NA	NA	30	2.96	583	29	4.38	337	1221	44.14508	-70.82111	155
3456	NA	NA	60	3.68	930	60	5.23	695	2330	44.03353	-70.73500	138
n	114	114	126	126	126	126	126	126	126	126	126	126
range	0.1-10.9	17.4 - 28.1	27-102	2.25-4.22	516-1054	20-79	1.96-5.29	22.4-695	926-2604	43.256-45.866	-70.936 - -67.7029	0-386
Mean	3.6	22.6	57.3	3.2	753	38.8	3.3	369	1987	44.526	-69.454	102.1
Median	2.5	22.9	55.5	3.3	770	34.0	3.1	340	1994	44.363	-69.535	94.5

[a] DO_{hyp} is the dissolved oxygen measurement 1 m from the bottom at the deepest point of the lake; T_{epi} is the lake temperature in °C at 1 m depth; Maximum (mm d^{-1}), average (mm d^{-1}), and cumulative precipitation (mm) from January and May of the year to sampling time. Precipitation and temperature data were obtained from the Prism Climate Group (2020) at http://prism.oregonstate.edu/ [Accessed 10th March 2020]. Precipitation and temperature data include two time periods: January 1st and May 1st to the sampling date. Baseline for degree days is 0 °C.
[b] Maine lake identifier accessed at http://www.lakesofmaine.org/your-lake.html.
[c] Elevation data accessed at http://www.lakesofmaine.org/your-lake.html.

Table S3. Pearson rank correlations for the climate/weather data. Correlations with $p < 0.01$ are denoted by *.

	Max. Precip. January	Average Precip. January	Sum Precip. January	Max. Precip. May	Average Precip. May	Sum Precip. May	T_{epi}	Degree-Day May	Elevation
log EpiP	-0.111	-0.29	-0.092	-0.240*	-0.298*	-0.193	0.333*	-0.093	-0.184
log Al:P	0.303*	0.338*	0.386*	0.288*	0.371*	0.394*	-0.271*	0.198	0.023
log P_{BD}	-0.291*	-0.322*	-0.372*	-0.276*	-0.365*	-0.398*	0.340*	-0.184	0.006
Ag:WA	-0.096	-0.050	-0.122	-0.115	0.278*	-0.288*	0.411*	-0.114	-0.267*
AdjAg:LA	-0.090	0.210	-0.104	0.011	-0.064	-0.172	0.326*	-0.094	-0.213
Z_{avg}	-0.079	-0.184	-0.119	0.084	-0.005	-0.048	-0.152	0.044	0.161
DOC	-0.053	-0.006	0.055	-0.012	-0.001	0.137	0.001	0.174	-0.263*

Table S4. Multiple linear regression equation coefficients for predicting lake epilimnetic P. Model ranking is based on data presented in Table 2.

	Models	**intercept**	**log Al:P**	**log P_{BD}**	Z_{avg}	**%Ag:WA**	**%AdjAg:LA**	**Ag:LA**	**DOC**	**pH**
1	log Al:P + Z_{avg} + AdjAg:LA + DOC	1.0332	-0.1273		-0.0131		3.86×10^{-3}		0.0479	
2	log Al:P + Z_{avg} + Ag:WA + DOC	0.9804	-0.1090		-0.0128	0.0138			0.0462	
3	log P_{BD} + Z_{avg} + AdjAg:LA + DOC	0.7057		0.1435	-0.0132		3.78×10^{-3}		0.0503	
4	log Al:P + Z_{avg} + Ag:LA + DOC	1.0981	-0.1313		-0.0137			0.0480	0.0380	
5	log Al:P + Z_{avg} + Ag:WA + pH	0.5582[a]	-0.0864		-0.0145	0.0123				0.0814
6	log Al:P + Z_{avg} + AdjAg:LA	1.2402	-0.1275		-0.0153		3.88×10^{-3}			
7	log P_{BD} + Z_{avg} + Ag:WA + pH	0.2624[a]		0.0923	-0.0145	0.0126				0.0926
8	log Al:P + Z_{avg} + Ag:WA	1.1740	-0.1077		-0.0148	0.0140				
9	log Al:P + Z_{avg} + Ag:LA	1.2423	-0.1271		-0.0131			0.0618		
10	log P_{BD} + Z_{avg} + Ag:WA	0.9020		0.1179	-0.0128			0.0152		
	Z_{avg} + Ag:WA +DOC	0.6989			-0.0112	0.0261			0.0447	
	Z_{avg} + Ag:WA	0.8898			-0.0132	0.0265				

[a] The p-value for these parameters is > 0.01.

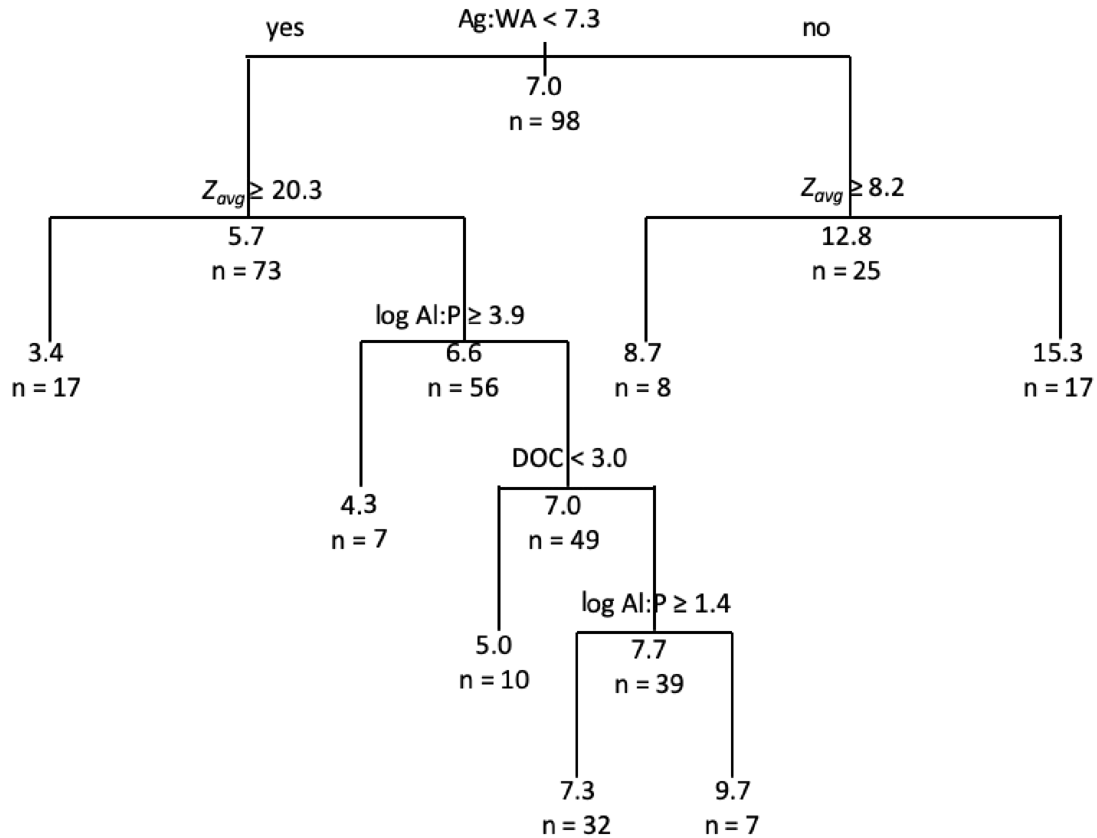


Figure S1. Regression tree analysis for August epilimnetic P (μg L^{-1}). Regression threshold values represent the mean epilimnetic P concentration. The left side of each split branch is a positive conditional statement. Ag:WA is the percent watershed agricultural area to watershed area; Z_{avg} is the area-averaged depth; Al:P is the sediment $Al_{BD+NaOH}$:P_{BD} molar ratio; and DOC is the dissolved organic carbon concentration.

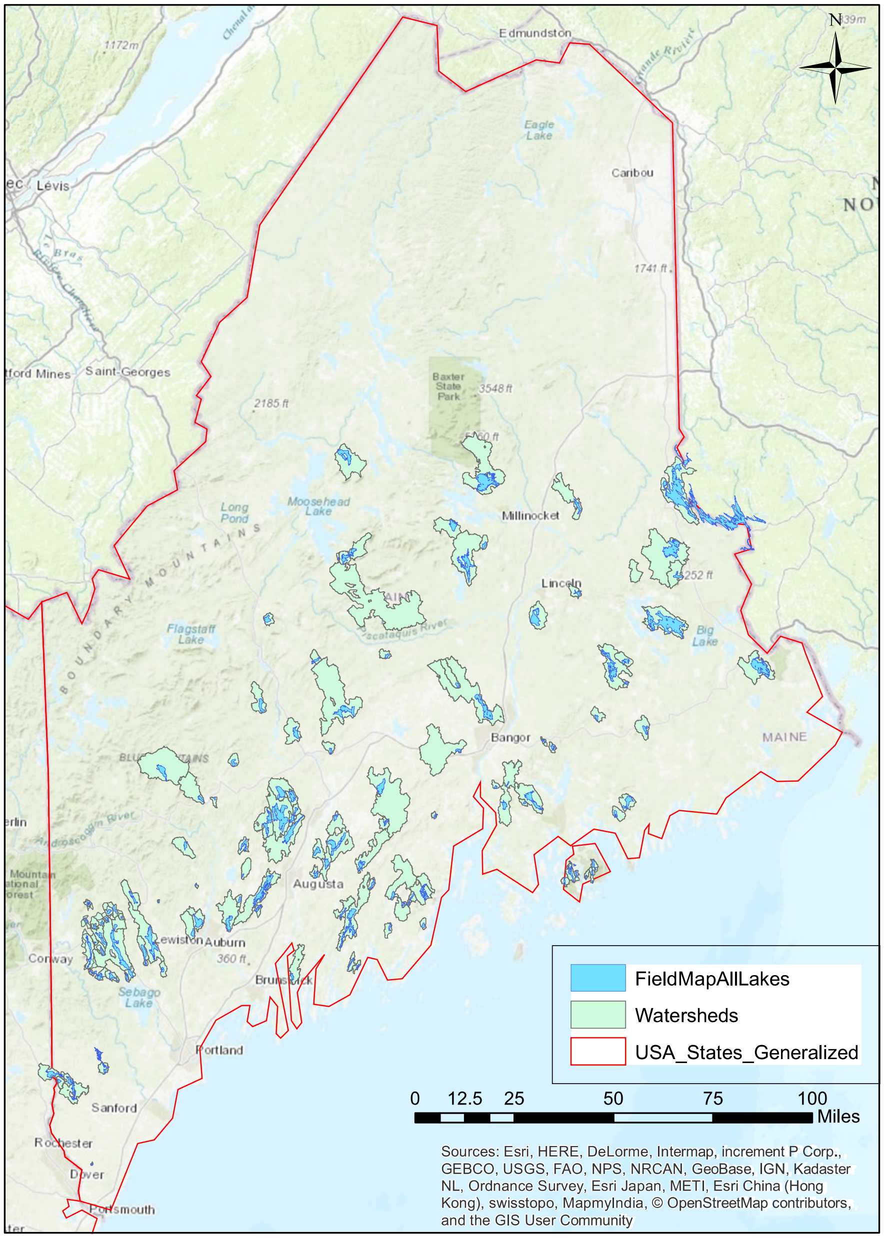
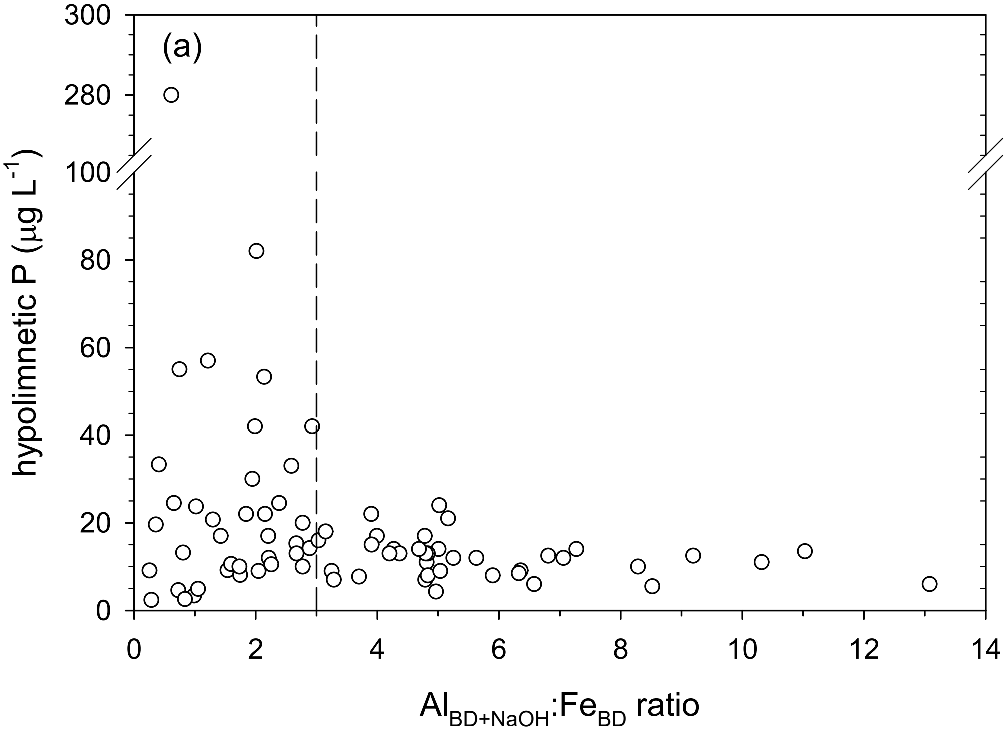


Figure S2: Map of all study sites.



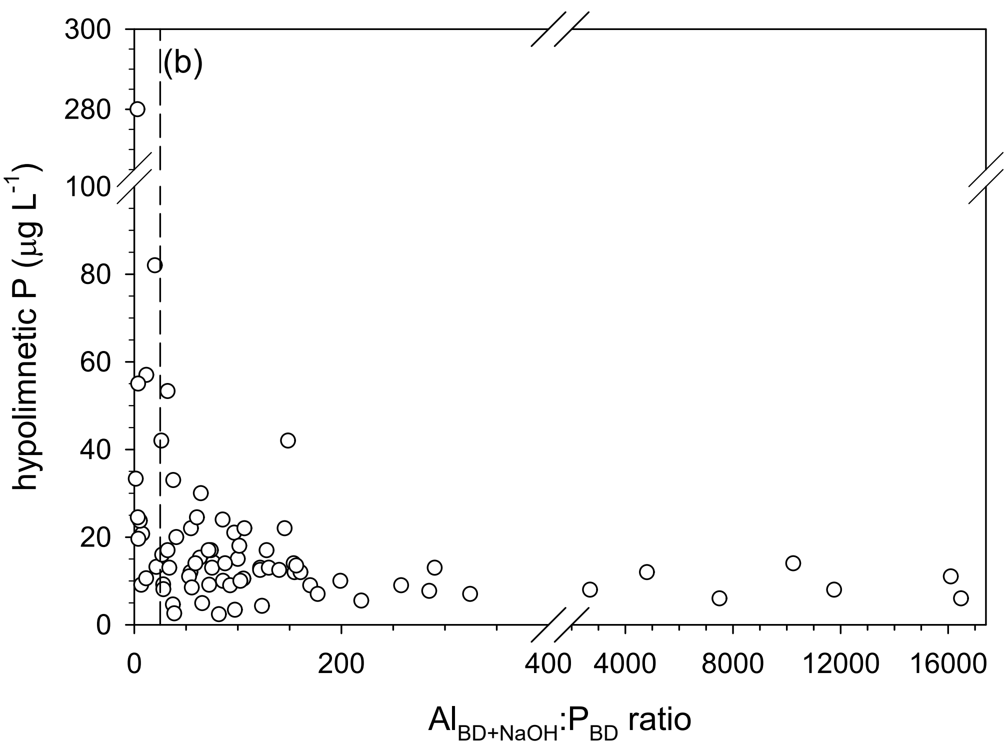


Figure S3. (a) Sediment $Al_{BD+NaOH}$:Fe_{BD} molar ratio versus hypolimnetic P (µg L^{-1}). The dashed line shows $Al_{BD+NaOH}$:Fe_{BD} ratio = 3; (b) sediment $Al_{BD+NaOH}$:P_{BD} molar ratio versus hypolimnetic P. The dashed line shows $Al_{BD+NaOH}$:P_{BD} molar ratio = 25.

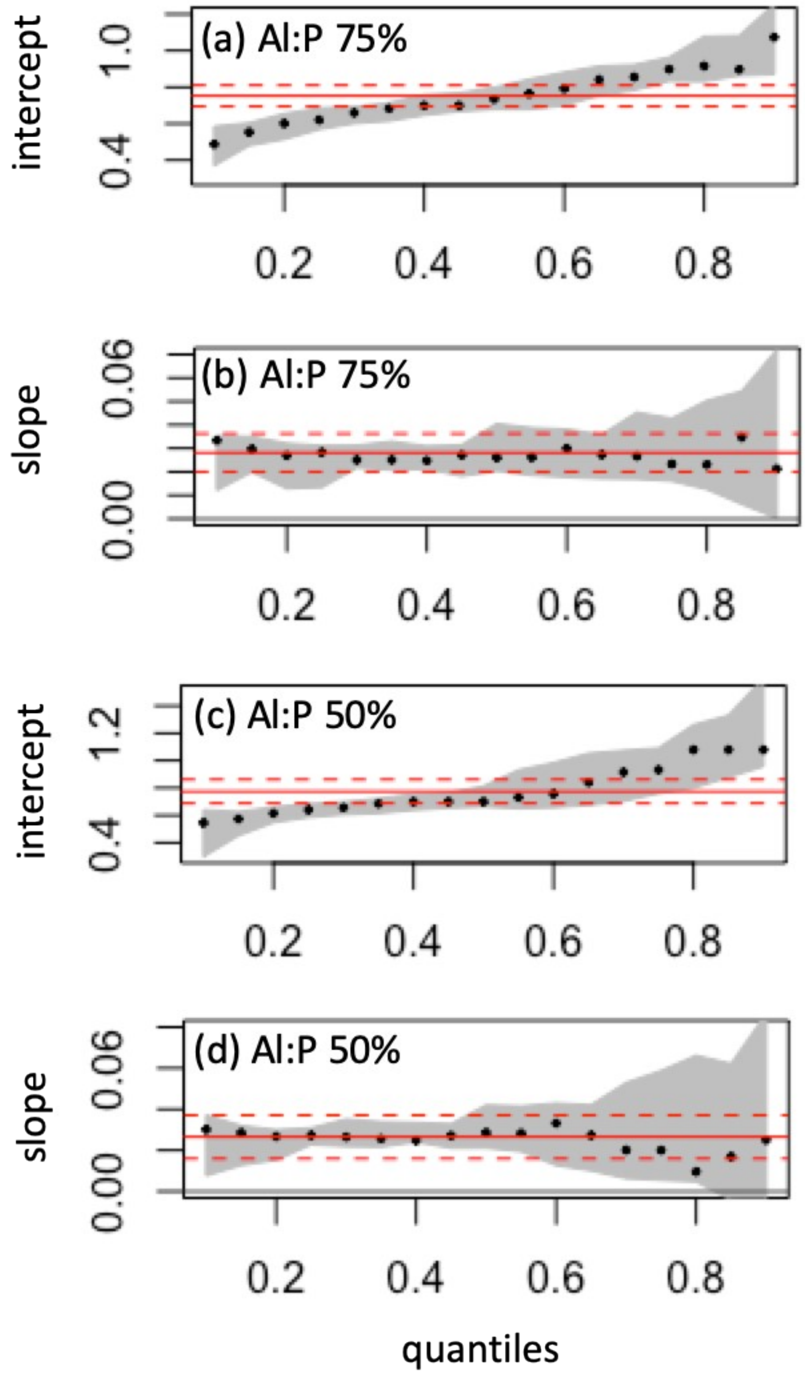


Figure S4. Intercepts and slopes for log epilimnetic P = $b_0(\tau) + b_1(\tau)$ log Ag:WA + ε. The QR models are based on the lower 75th percentile Al:P versus log epilimnetic P (a and b); and the lower 50th percentile Al:P versus log epilimnetic P (c and d). Model intercepts (b_0) and slopes (b_1) are shown as black dotted lines, gray areas are 95% confidence intervals, and red lines are the linear regression estimates with their corresponding 95% confidence intervals.

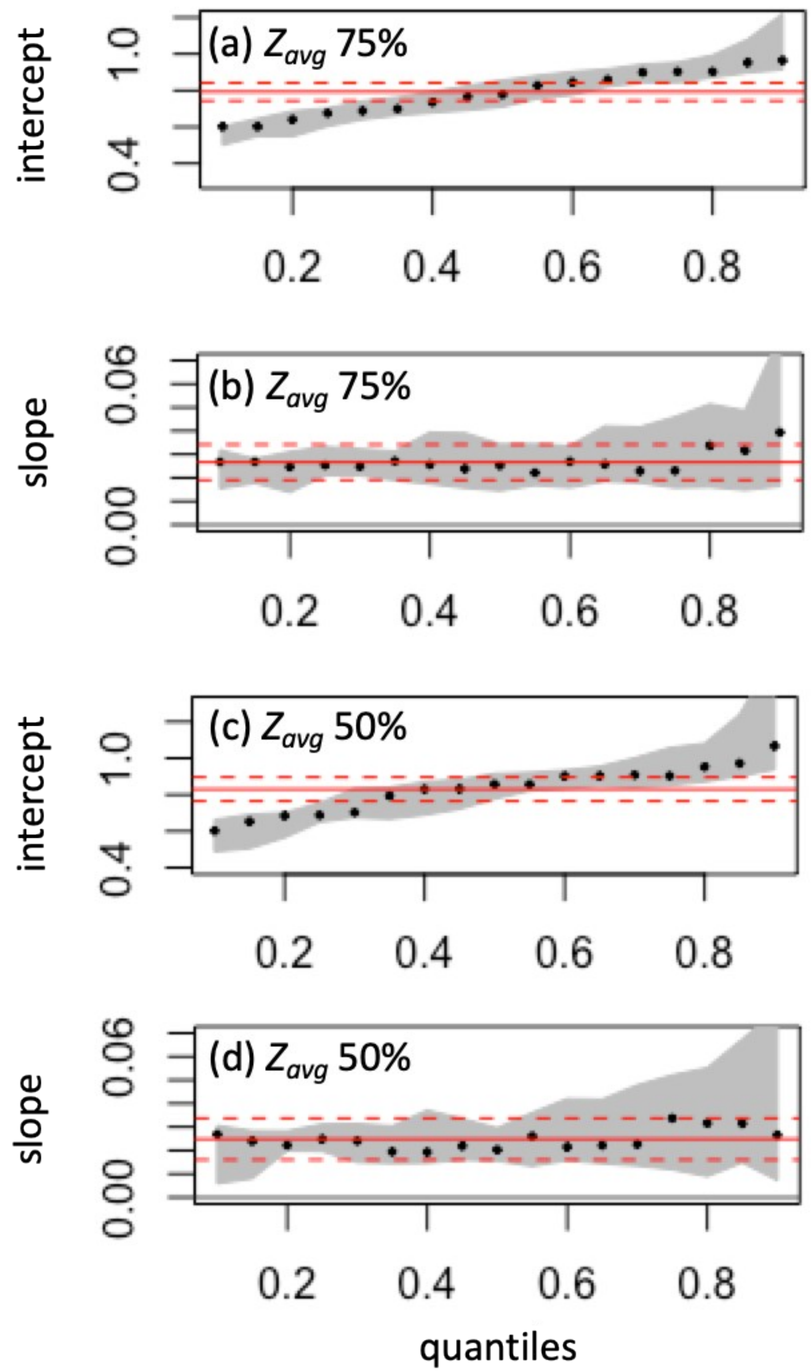


Figure S5. Intercepts and slopes for log epilimnetic P = $b_0(\tau) + b_1(\tau)$ log Ag:WA + ε. The QR models are based on the lower 75th percentile Z_{avg} versus log epilimnetic P (a and b); and the lower 50th percentile Z_{avg} versus log epilimnetic P (c and d). Model intercepts (b_0) and slopes (b_1) are shown as black dotted lines, gray areas are 95% confidence intervals, and red lines are the linear regression estimates with their corresponding 95% confidence intervals.

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