Supplement of Biogeosciences, 20, 5211–5228, 2023
https://doi.org/10.5194/bg-20-5211-2023-supplement

Biogeosciences Open Access EGU

Supplement of

The influence of carbon cycling on oxygen depletion in north-temperate lakes

Austin Delany et al.

Correspondence to: Austin Delany (addelany@gmail.com)

Supplemental Material

These materials provide support for the manuscript. The tables include detailed information on model configuration and model fit metrics. The additional figures provide information related to the analysis and discussion of topics in the manuscript.

TABLES

Table S1. RMSE values for epimlinetic DO, hypolimnetic DO, epilimnetic DOC, and Secchi Depth. Values are separated into calibration (1995-2009), validation (2010-2014), and full time series (1995-2014).

Lake / Variable	RMSE Calibration	RMSE Validation	RMSE Full Time Series
DO_epi (g m^{-3})			
ME	1.99	1.84	1.96
MO	1.92	2.11	1.96
TR	0.77	0.74	0.76
AL	2.06	1.89	2.02
BM	0.99	0.94	0.98
SP	0.89	1.09	0.94
DO_hypo (g m^{-3})			
ME	1.44	1.22	1.39
MO	1.68	1.65	1.67
TR	1.54	1.97	1.66
AL	2.79	2.77	2.79
BM	1.82	2.40	1.98
SP	2.01	2.77	2.25

DOC_epi (g m^{-3})			
ME	1.19	1.81	1.36
MO	1.19	1.55	1.28
TR	0.31	0.41	0.34
AL	0.50	0.70	0.55
BM	0.53	0.65	0.56
SP	0.47	0.69	0.53
DOC_hypo (g m^{-3})			
ME	0.83	1.23	0.94
MO	1.32	0.74	1.20
TR	0.32	0.30	0.31
AL	0.55	0.67	0.58
BM	0.58	0.50	0.57
SP	0.61	0.57	0.57
Secchi (m)			
ME	2.29	2.56	2.35
MO	2.09	1.69	2.00
TR	0.59	1.00	0.70
AL	0.49	0.83	0.59
BM	0.66	0.91	0.73
SP	0.82	1.72	1.01

Table S2. Results from a Mann-Kendall trend analysis on lake NPP and average summer epilimnetic (epi) total phosphorus concentration (TP) for each lake. Z score and P-values are both shown. *p*-values less than 0.1 were considered significant.

Lake	NPP Z score	NPP _*p*-value	Epi TP Z score	Epi TP *p*-value
ME	-1.97	**0.05**	-1.85	**0.06**
MO	-0.75	0.46	-0.94	0.35
TR	0.42	0.67	-0.30	0.77
AL	-1.85	**0.06**	-2.70	**0.01**
BM	0.55	0.58	0.16	0.87
SP	0.81	0.42	0.49	0.63

Table S3. OC average annual budget table for each lake. Allochthonous OC (oc_alloch) and autochthonous OC (oc_auto) fluxes are sources for each system. OC burial (oc_burial), OC export (oc_export), sediment respiration (resp_sed), and water column respiration (resp_wc) are all fates of OC within each system. All fluxes are in units of $gC\ m^{-2}\ year^{-1}$.

Lake	oc_alloch	oc_auto	oc_burial	oc_export	resp_sed	resp_wc
ME	36.51	363.17	48.56	20.51	51.77	278.89
MO	59.74	424.07	68.06	54.29	52.15	309.98
TR	28.89	102.82	21.25	7.99	12.94	89.57
AL	31.63	94.84	43.13	22.82	8.96	51.46
BM	13.65	52.09	6.55	5.60	11.35	42.23
SP	12.77	77.06	4.73	3.87	18.12	63.52

Table S4. Fit values for the three free parameters in the model. These include the slope of the irradiance-productivity curve (IP), the respiration rate of sediment OC (R_sed), and the respiration rate of labile DOC (R_DOCL). Standard deviations for parameter uncertainty distributions are equal to 20% of the values.

Lake	IP ($gCd^{-1}(Wm^{-2})^{-1}$)	R_sed (day^{-1})	R_DOCL (day^{-1})
ME	0.045	0.40	0.025
MO	0.045	0.40	0.022
TR	0.015	0.08	0.015
AL	0.015	0.06	0.02
BM	0.015	0.08	0.015
SP	0.015	0.12	0.02

Table S5. Manually calibrated values that vary across lake systems. These include the fitting coefficient for light extinction of DOC (LEC_doc), maximum daily productivity (Pmax), inflow concentrations for recalcitrant DOC (DOCR_in), the inflow concentrations for recalcitrant POC (POCR_in), and initial condition concentrations for DOCR, DOCL, and POCR (DOCR initial, DOCL initial, POCR initial). MO does not have set DOCR_in or POCR_in values because they are computed from the outflow of ME. The initial condition POCL concentration was zero for all lakes.

Lake	LEC_doc ($m^2 g^{-1}$)	Pmax ($g\ m^{-3}\ day^{-1}$)	DOCR_in ($g\ m^{-3}$)	POCR_in ($g\ m^{-3}$)	DOCR initial ($g\ m^{-3}$)	DOCL initial ($g\ m^{-3}$)	POCR initial ($g\ m^{-3}$)
ME	0.02	5.0	10.0	2.0	5	0	0.5
MO	0.02	5.0	NA	NA	5	0	0.5
TR	0.03	0.5	5.0	6.0	2.5	0.5	0.2
AL	0.06	1.5	4.0	2.0	3	0	0.2
BM	0.02	0.5	7.0	2.0	3.5	0.5	0.2
SP	0.02	1.5	8.0	3.0	3.5	0.5	0.2

Table S6. Results for the Wilcoxon significance test performed on the average annual OC sources and fates for our study lakes. Note, any p-value less than 0.05 was considered significant. All non-significant differences between lakes are indicated by "NS".

Autochthonous OC						
	ME	MO	TR	AL	BM	SP
ME						
MO	*					
TR	*	*				
AL	*	*	*			
BM	*	*	*	*		
SP	*	*	*	*	NS	
Allocthonous OC						
	ME	MO	TR	AL	BM	SP
ME						
MO	*					
TR	*	*				
AL	*	*	*			
BM	*	*	*	*		
SP	*	*	*	*	NS	
Water Column Respiration						
	ME	MO	TR	AL	BM	SP
ME						
MO	NS					
TR	*	*				
AL	*	*	*			
BM	*	*	*	NS		
SP	*	*	*	*	*	
Sediment Respiration						

	ME	MO	TR	AL	BM	SP
ME						
MO	NS					
TR	*	*				
AL	*	*	*			
BM	*	*	*	*		
SP	*	*	*	*	NS	
OC Export						
	ME	MO	TR	AL	BM	SP
ME						
MO	*					
TR	*	*				
AL	NS	*	*			
BM	*	*	*	*		
SP	*	*	*	*	*	
OC Burial						
	ME	MO	TR	AL	BM	SP
ME						
MO	NS					
TR	*	*				
AL	*	*	*			
BM	*	*	*	*		
SP	*	*	*	*	NS	

Table S7. The Nash-Sutcliffe model efficiency coefficient (NSE) and the Kling-Gupta Efficiency (KGE) for the model state variables over the model validation period.

Lake	Epi DO NSE	Hypo DO NSE	Epi DOC NSE	Hypo DOC NSE	Secchi NSE	Epi DO KGE	Hypo DO KGE	Epi DOC KGE	Hypo DOC KGE	Secchi KGE
ME	0.39	0.86	-7.81	-2.06	-0.74	0.47	0.80	-0.32	0.10	-0.10
MO	0.02	0.71	-3.90	-2.27	-0.42	0.48	0.66	-0.29	-0.03	0.30
TR	0.72	0.37	-0.99	-0.67	-3.31	0.90	0.73	0.022	-0.01	-0.42
AL	-1.45	0.11	0.31	0.14	-0.32	0.40	0.60	0.35	0.05	0.08
BM	0.27	0.46	-0.77	-0.41	-0.80	0.67	0.67	-0.07	0.10	0.07
SP	-0.30	-0.30	-2.75	-1.79	-2.19	0.45	0.35	0.01	-0.17	-0.25

FIGURES

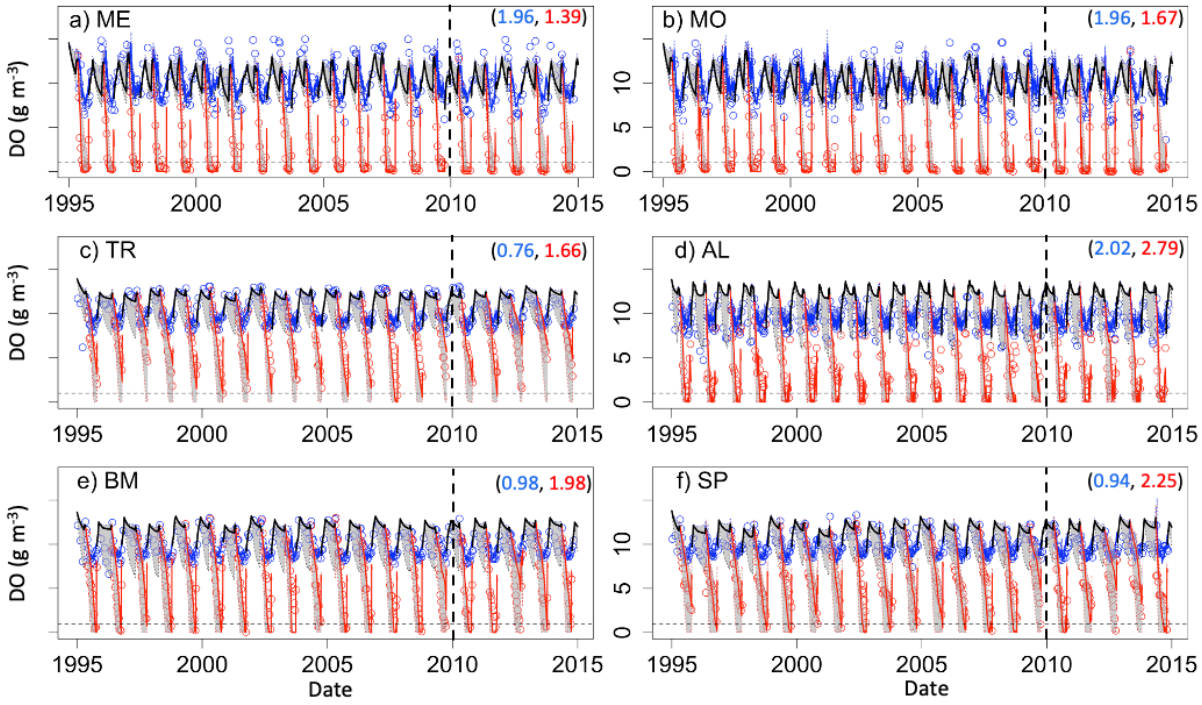

Figure S1. Dissolved oxygen (DO) time series for the years for all years. Model predictions are represented by lines, and points represent the observational data. Epilimnetic DO values are indicated in blue and Hypolimnetic DO values are indicated in red. RMSE values (Epi, Hypo) are included in the upper right of each panel. The calibration period (1995-2010) and validation period (2010-2015) are separated by a vertical dashed black line. Uncertainty is represented by gray shading.

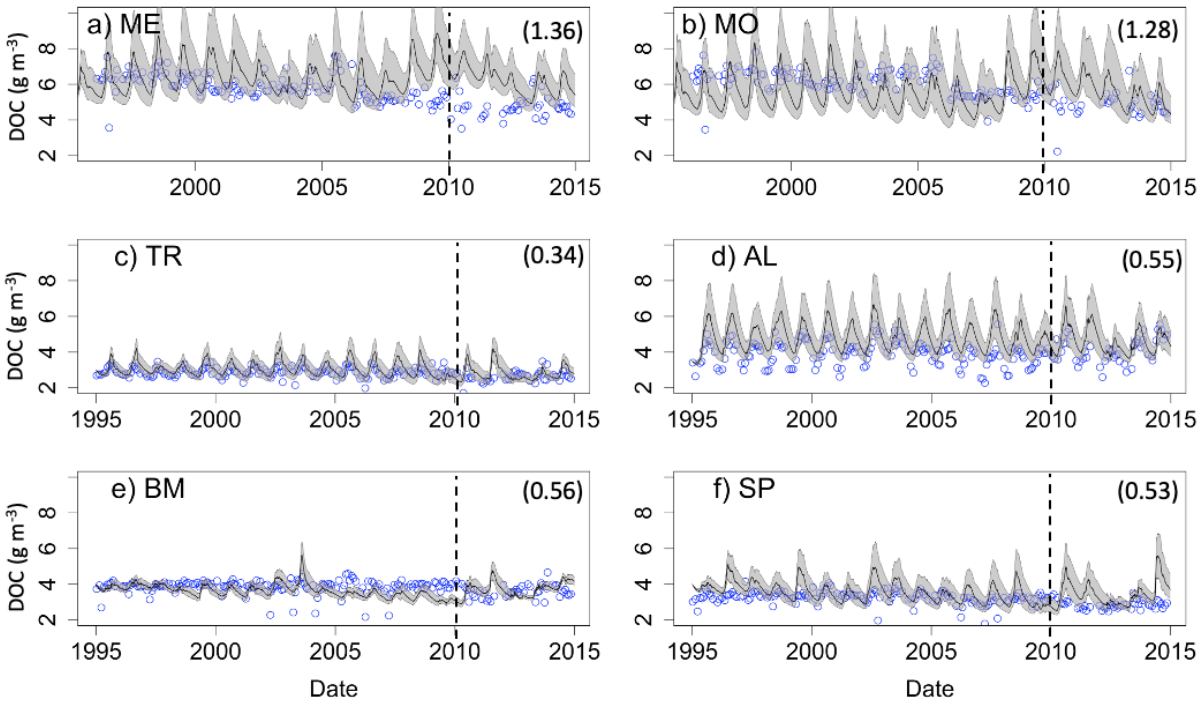

Figure S2. Dissolved organic carbon (DOC) time series for all years. Model predictions are represented by lines, and points represent the observational data. RMSE values are included for each lake. The calibration period (1995-2009) and validation period (2010-2014) are separated by a vertical dashed black line. Uncertainty is represented by gray shading.

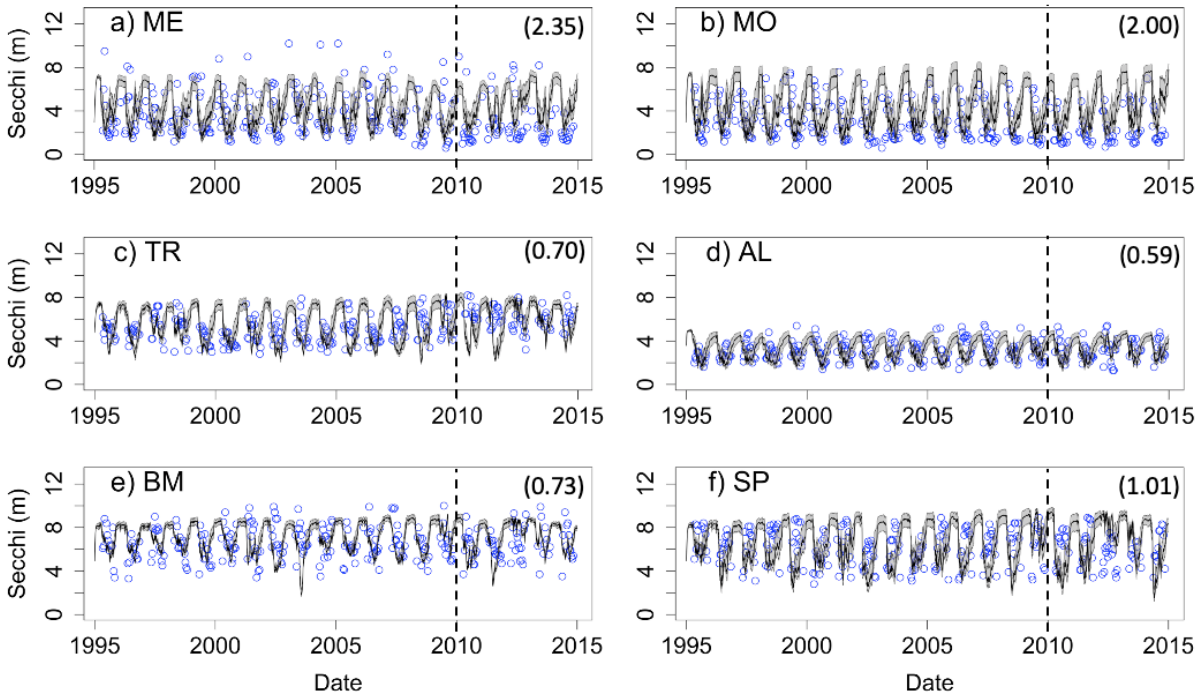

Figure S3. Secchi Depth time series for the all years. Model predictions are represented by lines, and points represent the observational data. RMSE values are included for each lake. The calibration period (1995-2009) and validation period (2010-2014) are separated by a vertical dashed black line. Uncertainty is represented by gray shading.

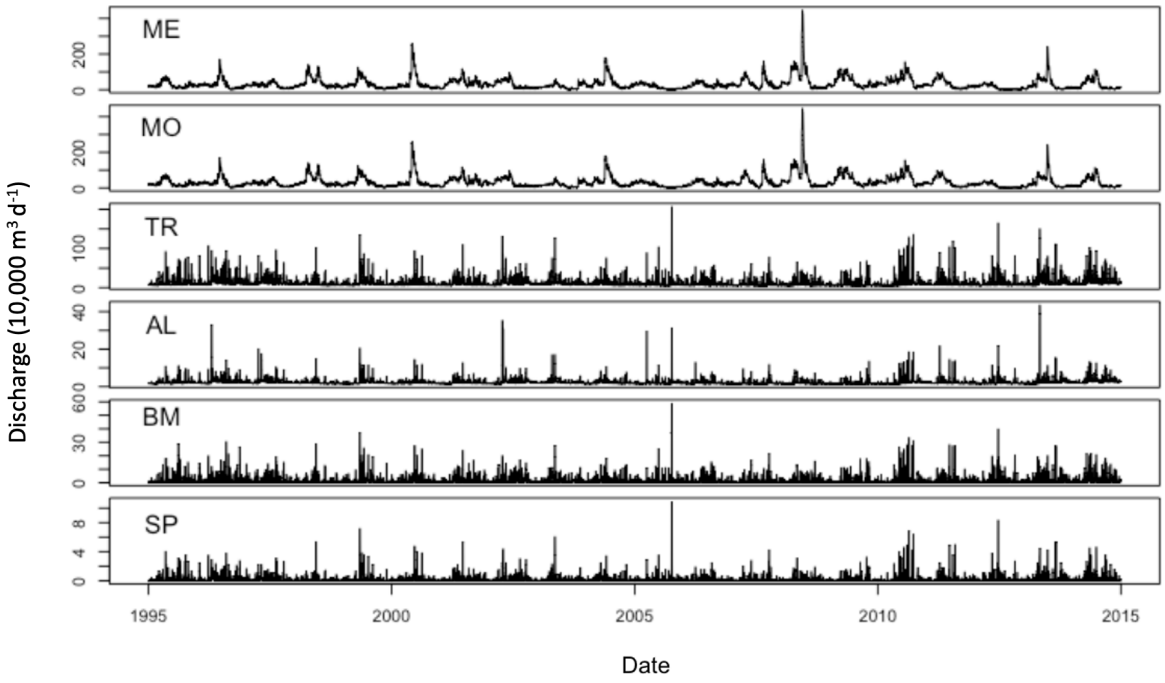

Figure S4. Derived lake discharge information for inflow hydrology over the full time series. Note that the y-axis values are in units of 10,000 m^3 d^{-1}.

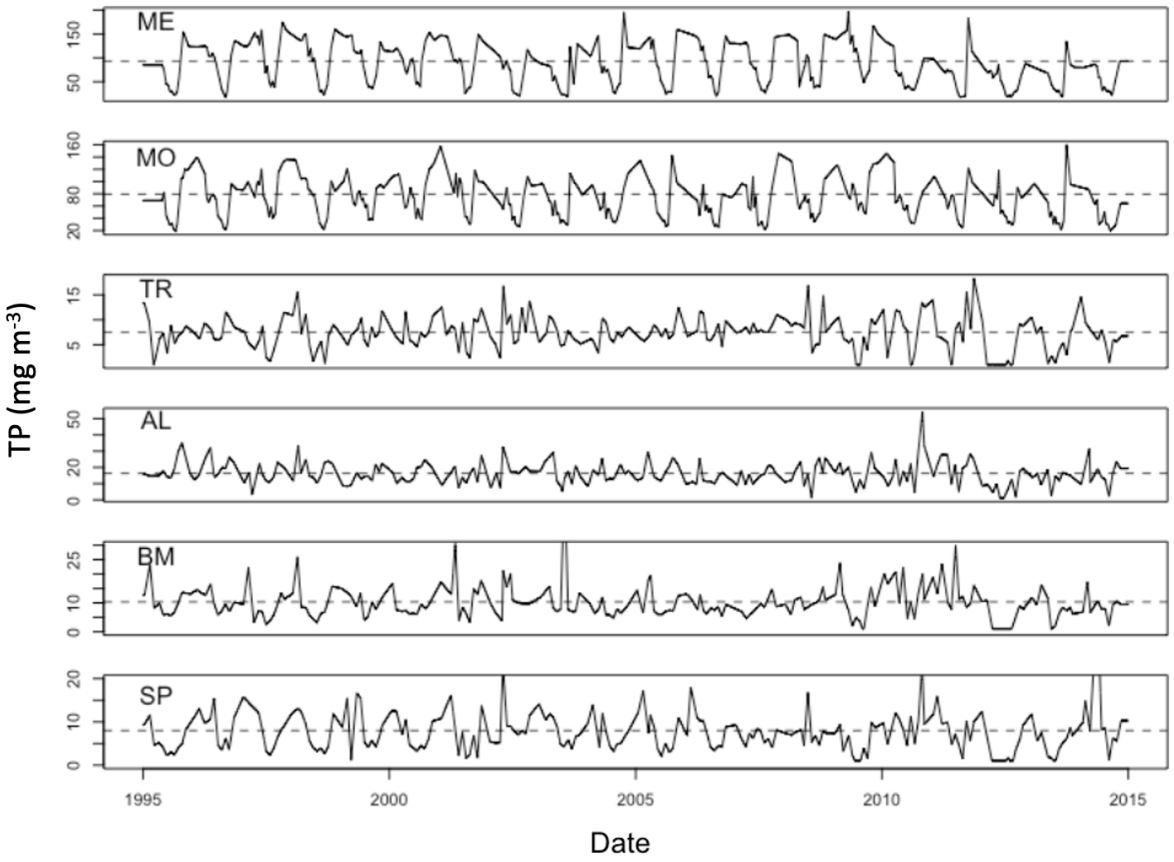

Figure S5. Total phosphorus concentrations [mg m^{-3}] over the full time series. Values are interpolated to a daily time step from observational data. The long term mean for total phosphorus is also plotted for each lake (dashed line).

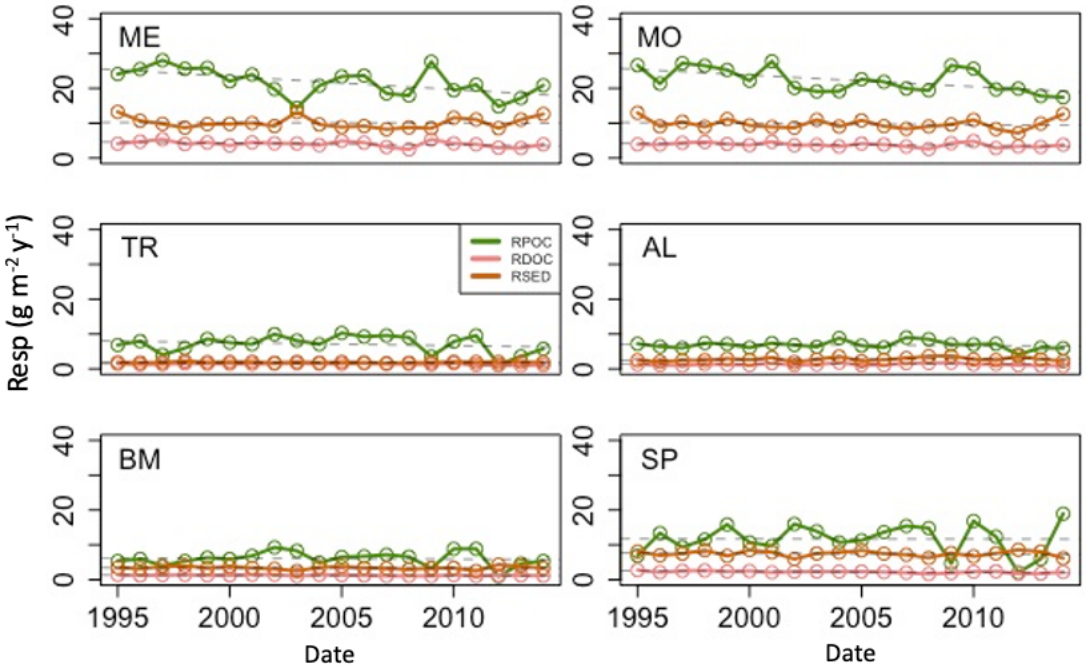

Figure S6. Annual hypolimnetic OC respiration values over the full 20 year time series with associated trend lines (dashed). Components include calibrated POC water column respiration (green), DOC water column respiration (pink), and sediment respiration (orange).

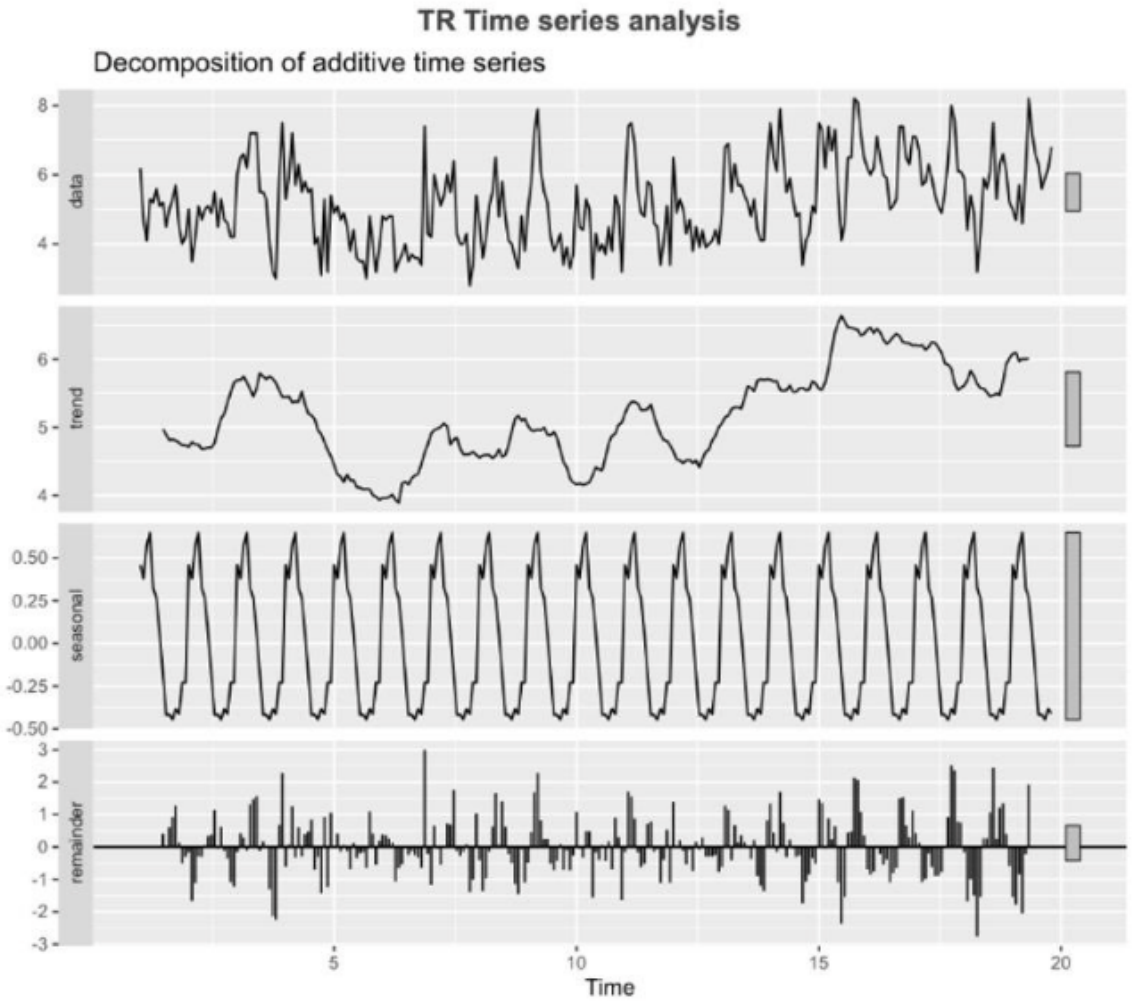

Figure S7. Time series decomposition for observed Secchi data for Trout Lake.