

Chapter 2 Supplemental

Methane-derived carbon gas fluxes from a tropical flood-pulse lake

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Table S1. AICc selection for 24 mixed effects models describing potential drivers of CO₂ and CH₄ diffusion (mg C L⁻¹ d⁻¹) in open, edge, and floodplain environments at Prek Konteil, Anlang Reang, and Kampong Preah during the high-water stage of the flood-pulse. Each control is a fixed effect, and environment sampled is a random effect.

		CO ₂ Diffusion (mg C m ⁻² d ⁻¹)		CH ₄ Diffusion (mg C m ⁻² d ⁻¹)	
Controls	Depth	ΔAICc	AICc Weight	ΔAICc	AICc Weight
1. Null		82.17	<0.000	66.58	<0.000
<i>Meteorology</i>					
2. Water temperature (°C)		89.50	<0.000	70.31	<0.000
3. Wind speed (m s ⁻¹)		5.58	0.054	31.67	<0.000
<i>Hydrology</i>					
4. Inundation time (days)		99.40	<0.000	81.51	<0.000
5. Distance into floodplain (m)		91.42	<0.000	71.56	<0.000
6. Water depth (m)		90.65	<0.000	65.43	<0.000
<i>Primary production</i>					
7. Chlorophyll a (ug L ⁻¹)	Surface	67.32	<0.000	44.86	<0.000
8.	Bottom	42.29	<0.000	25.08	<0.000
9. Chlorophyll b (ug L ⁻¹)	Surface	81.20	<0.000	57.85	<0.000
10.	Bottom	46.63	<0.000	34.31	<0.000
11. NO ₃ ⁻ / PO ₄ ³⁻	Surface	94.24	<0.000	62.17	<0.000
12.	Bottom	64.08	<0.000	12.43	0.002
13. SiOH ₄ ⁻ (umol L ⁻¹)	Surface	43.67	<0.000	70.16	<0.000
14.	Bottom	49.12	<0.000	43.20	<0.000
<i>Redox</i>					
15. O ₂ (mg L ⁻¹)	Surface	54.93	<0.000	0.00¹	0.993¹
16.	Bottom	25.34	<0.000	43.93	<0.000
17. NO ₃ ⁻ (umol L ⁻¹)	Surface	88.62	<0.000	59.54	<0.000
18.	Bottom	5.57²	0.055²	10.69²	0.005²
19. Fe _{Tot} (umol L ⁻¹)	Surface	78.52	<0.000	50.71	<0.000
20.	Bottom	74.84	<0.000	38.92	<0.000
21. Mn _{Tot} (umol L ⁻¹)	Surface	20.15	<0.000	31.00	<0.000
22.	Bottom	0.00¹	89.026¹	21.73	<0.000
23. SO ₄ ²⁻ (umol L ⁻¹)	Surface	95.33	<0.000	26.43	<0.000
24.	Bottom	69.99	<0.000	18.19	<0.000

¹Primary covariate, ²Secondary covariate

2A.0 Model Covariates

2A.1 Inundation Times

The amount of time that each sampling site was underwater per year, or its inundation time, was determined using remotely-sensed, synthetic aperture radar backscatter data in log-transformed decibels from the European Space Agency downloaded with Google Earth Engine Catalog (Torres et al., 2012; Gorelick et al., 2017). These data were collected by the Copernicus Sentinel-1A/B satellites in sun-synchronous polar orbit passing over Cambodia in intervals of 5 days, beginning April 2014. Satellite backscatter data were radiometrically calibrated and corrected for thermal noise and terrain. Backscatter increases with water on the landscape. Thus, backscatter data were plotted as a time series using the statistical and data visualization software R (R Core Team, 2019), smoothed using a loess spanning function of 0.2, and interrogated for inflection points when backscatter abruptly increased or returned to baseline levels as flood waters expanded or contracted over a site, respectively. Due to the satellite's temporal resolution, 5 days or the maximum error was subtracted from these inflection points, and the days between considered inundation time.

2A.2 Electron Acceptors

We measured electron acceptors for methanotrophy and overall *ER* in open-water, edge, and floodplain environments during the high-water ($n=36$) and falling-water stages of the flood pulse ($n=12$), in surface and bottom waters. These included dissolved O_2 ($mg\ L^{-1}$), the dissolved anions nitrate (NO_3^-), and sulfate (SO_4^{2-}), and the dissolved metals total iron (Fe_{Tot}) and total manganese (Mn_{Tot}) ($umol\ L^{-1}$). Phosphate (PO_4^{3-}) ($umol\ L^{-1}$) was also measured. Dissolved O_2 was measured using a YSI (6920) as described previously. Water was collected at each transect point and depth using a Van Dorn sampler, vacuum filtered through a pre-ashed 47 mm GF/C

filter (Whatman), placed in 60 mL opaque Nalgene bottles on ice and transported back to the University of Washington for analysis. Anions were analyzed using an ion chromatograph (Dionex 120 IC). Metals were analyzed using an inductively-coupled plasma optical emission spectrometer (ThermoFisher Scientific 61e ICP-OES, School of Environmental and Forest Sciences Soil Analytics Lab and Analytical Services Center).

2A.3 Chlorophyll

We also measured the photosynthetic pigments chlorophyll *a* and chlorophyll *b* within phytoplankton ($\mu\text{g L}^{-1}$) in open-water, edge, and floodplain environments during the high-water ($n=36$) and falling-water stages of the flood pulse ($n=12$), in surface and bottom waters. Water was collected at each transect point and depth using a Van Dorn sampler and vacuum filtered through a pre-ashed 47 mm GF/C filter (Whatman). This filter was then wrapped in foil and placed on ice for transport. Samples were stored at 4 °C in the Department of Chemistry at Royal University of Phnom Penh until analysis within 48 h of sample collection. Chlorophyll was extracted from each filter in a 90 % ethanol, 10 % supersaturated magnesium carbonate solution for 12 h prior to analysis using a fluorometer (AquaFluor Handheld Fluorometer/Turbidimeter). Prior to sample analysis, the fluorometer was calibrated with series of total chlorophyll reference standards (0, 10, 20, 50, 100, and 200 $\mu\text{g L}^{-1}$).

Chapter 3 Supplemental

High methanogenic fixation of carbon in a flood-pulse lake food web

Benjamin L. Miller¹

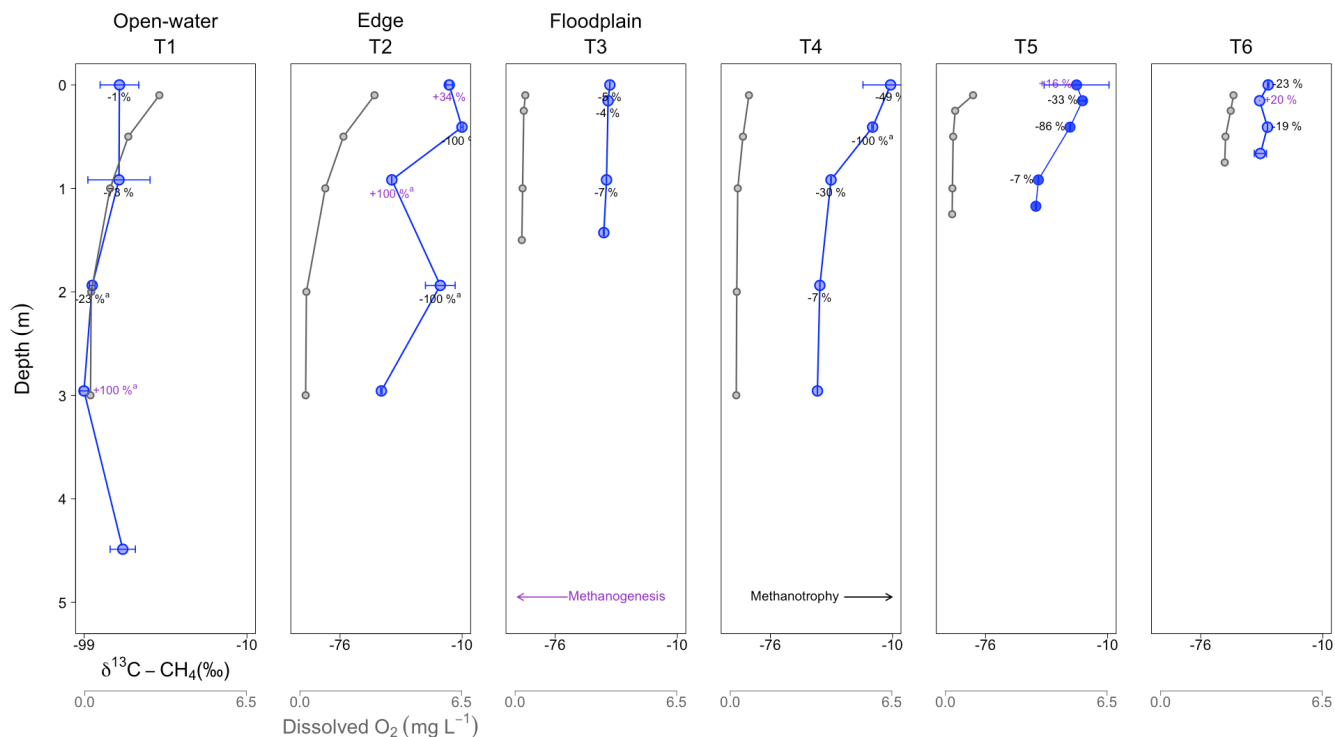
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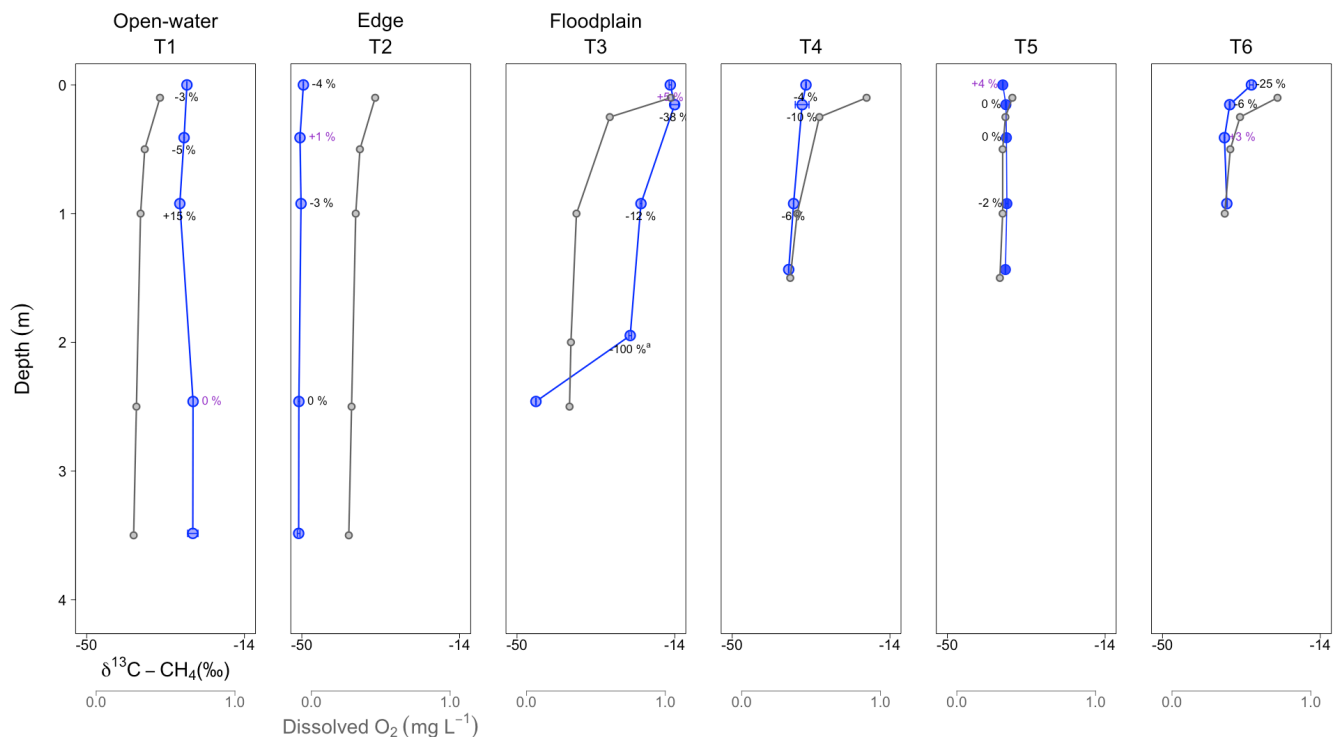
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^aChange exceeded 100% within the water column

Figure S1. Methanotrophy and methanogenesis in the water column expressed as a percent change between the $\delta^{13}\text{C}-\text{CH}_4 \pm \text{SE}$ (‰) measured at each depth based on an open-system vertical advection model in open-water, edge, and floodplain environments during the high-water stage of the TSL flood-pulse along the Anlang Reang transect (T1-T6). Depletion of $^{13}\text{C}-\text{CH}_4$ indicates water column methanogenesis, whereas enrichment of $^{13}\text{C}-\text{CH}_4$ indicates preferential consumption of $^{12}\text{C}-\text{CH}_4$ by methanotrophic bacteria. Methanotrophy frequently coincided with increases in dissolved O_2 (mg L^{-1}) at depth.



^aChange exceeded 100% within the water column

Figure S2. Methanotrophy and methanogenesis in the water column expressed as a percent change between the $\delta^{13}\text{C}-\text{CH}_4 \pm \text{SE}$ (‰) measured at each depth based on an open-system vertical advection model in open-water, edge, and floodplain environments during the high-water stage of the TSL flood-pulse along the Anlang Reang transect (T1-T6). Depletion of $^{13}\text{C}-\text{CH}_4$ indicates water column methanogenesis, whereas enrichment of $^{13}\text{C}-\text{CH}_4$ indicates preferential consumption of $^{12}\text{C}-\text{CH}_4$ by methanotrophic bacteria. Methanotrophy frequently coincided with increases in dissolved O_2 (mg L^{-1}) at depth.

Table S1. AICc selection for mixed effects models describing potential biogeochemical controls on methanogenesis and methanotrophy ($\text{mg C-CH}_4 \text{ m}^{-2} \text{ d}^{-1}$) in TSL during the high-water stage of the flood-pulse.

	Controls	Methanogenesis ($\text{mg C-CH}_4 \text{ m}^{-2} \text{ d}^{-1}$)		Methanotrophy ($\text{mg C-CH}_4 \text{ m}^{-2} \text{ d}^{-1}$)	
		ΔAICc	AICc Weight	ΔAICc	AICc Weight
1.	Null	230.97	<0.000	53.38	<0.000
	<i>Hydrology</i>				
2.	Water temperature ($^{\circ}\text{C}$)	218.14		53.91	
3.	Inundation time (days)	232.39	<0.000	48.51	<0.000
4.	Distance into floodplain (m)	207.33	<0.000	20.99	<0.000
5.	Floodplain water depth (m)	0.00¹	0.999¹	33.24	<0.000
	<i>Primary production</i>				
6.	Chlorophyll a ($\mu\text{g L}^{-1}$)	190.66	<0.000	35.67	<0.000
7.	Chlorophyll b ($\mu\text{g L}^{-1}$)	212.74	<0.000	62.15	<0.000
8.	$\text{NO}_3^- / \text{PO}_4^{3-}$	161.53	<0.000	42.97	<0.000
9.	SiOH_4^- ($\mu\text{mol L}^{-1}$)	49.85	<0.000	9.12	0.001
	<i>Redox</i>				
10.	O_2 (mg L^{-1})	217.54	<0.000	0.00¹	0.999¹
11.	NO_3^- ($\mu\text{mol L}^{-1}$)	26.59	<0.000	41.59	<0.000
12.	Fe_{Tot} ($\mu\text{mol L}^{-1}$)	152.62	<0.000	11.21	<0.000
13.	Mn_{Tot} ($\mu\text{mol L}^{-1}$)	228.89	<0.000	14.84	<0.000
14.	SO_4^{2-} ($\mu\text{mol L}^{-1}$)	17.56	0.001	32.62	<0.000

¹Primary control

3A.0 Model Covariates

3A.1 Inundation Times

Inundation times at each point along the Kampong Preah, Anlang Reang, and Prek Konteil transects were determined using remotely-sensed, synthetic aperture radar backscatter data. Raw data were log-transformed in decibels from the European Space Agency downloaded with Google Earth Engine Catalog (Torres et al., 2012; Gorelick et al., 2017). These data were collected by the Copernicus Sentinel-1A/B satellites in sun-synchronous polar orbit passing over Cambodia in intervals of 5 days, beginning April 2014. Satellite backscatter data were radiometrically calibrated and corrected for thermal noise and terrain. Backscatter increases with water on the landscape. Thus, backscatter data were plotted as a time series using the statistical and data visualization software R (R Core Team, 2019), smoothed using a loess spanning function of 0.2, and interrogated for inflection points when backscatter abruptly increased or returned to baseline levels as flood waters expanded or contracted over a site, respectively. Due to the satellite's temporal resolution, 5 days or the maximum error was subtracted from these inflection points, and the days between considered the amount of time a site was underwater, or its inundation time.

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point and depth using a Van Dorn sampler, vacuum filtered through a pre-ashed 47 mm GF/C filter (Whatman), placed in 60 mL opaque Nalgene bottles on ice and transported back to the University of Washington for analysis. Anions were analyzed using an ion chromatograph (Dionex 120 IC). Metals were analyzed using an inductively-coupled plasma optical emission spectrometer (ThermoFisher Scientific 61e ICP-OES, School of Environmental and Forest Sciences Soil Analytics Lab and Analytical Services Center).

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Chapter 4 Supplemental

Magnitudes and drivers of greenhouse gas fluxes in floodplain ponds during drawdown and inundation by the Three Gorges Reservoir

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Table S1. AIC_c results for five candidate models predicting the partial pressures of CH₄, CO₂, and N₂O in floodplain ponds and the submerged floodplain. Models with relative support (over two ΔAIC_c units) are starred.

Model Name	Floodplain Ponds			Submerged Floodplain		
	AIC _c	ΔAIC _c	Weight	AIC _c	ΔAIC _c	Weight
PCH₄	(df=35)			(df=71)		
Null model	368.58	26.95	0.000	841.55	34.62	0.000
Partial <i>in-situ</i> production	364.39	22.76	0.000	837.30	30.37	0.000
Full <i>in-situ</i> production	352.27	10.65	0.005	812.26	5.33	0.065
Partial <i>in-situ</i> respiration	363.97	22.34	0.000	837.77	30.84	0.000
Full <i>in-situ</i> respiration	341.61	0.00*	0.995*	806.93	0.00*	0.935*
PCO₂	(df=35)			(df=71)		
Null model	455.15	41.27	0.000	800.96	39.16	0.000
Partial <i>in-situ</i> production	448.76	34.88	0.000	790.01	28.21	0.000
Full <i>in-situ</i> production	418.96	5.07	0.073	765.36	3.56	0.144
Partial <i>in-situ</i> respiration	444.96	31.07	0.000	793.09	31.29	0.000
Full <i>in-situ</i> respiration	413.88	0.00*	0.927*	761.80	0.00*	0.856*
PN₂O	(df=35)			(df=71)		
Null model	-95.76	0.00*	0.743*	31.92	36.26	0.000
Partial <i>in-situ</i> production	-92.15	3.61	0.122	18.63	22.96	0.000
Full <i>in-situ</i> production	-65.72	30.04	0.000	27.93	32.26	0.000
Partial <i>in-situ</i> respiration	-92.35	3.40	0.135	4.33	0.00*	0.948*
Full <i>in-situ</i> respiration	-74.23	21.53	0.000	1.46	5.79	0.052

Table S2. AIC_c results for six candidate models predicting the diffusive fluxes of CH₄, CO₂, and N₂O from floodplain ponds and the submerged floodplain. Models with relative support (over two ΔAIC_c units) are starred.

Model Name	Floodplain Ponds			Submerged Floodplain		
	AIC _c	ΔAIC _c	Weight	AIC _c	ΔAIC _c	Weight
Diffusive CH₄ fluxes	(df=202)			(df=71)		
Null model	1337.29	0.14	0.472	70.12	0.00*	0.995*
Partial <i>in-situ</i> production	1337.15	0.00	0.507	81.96	11.85	0.003
Full <i>in-situ</i> production	1356.43	19.28	0.000	97.60	27.49	0.000
Partial <i>in-situ</i> respiration	1343.54	6.39	0.021	81.90	11.79	0.002
Full <i>in-situ</i> respiration	1352.23	15.08	0.000	95.92	25.81	0.000
Diffusive CO₂ fluxes	(df=197)			(df=71)		
Null model	2861.12	17.11	0.000	915.37	11.94	0.002
Partial <i>in-situ</i> production	2861.35	17.33	0.000	917.48	14.05	0.001
Full <i>in-situ</i> production	2853.87	9.86	0.007	909.50	6.08	0.045
Partial <i>in-situ</i> respiration	2856.87	12.86	0.002	916.06	12.63	0.002
Full <i>in-situ</i> respiration	2844.01	0.00*	0.991*	903.43	0.00*	0.950*
Diffusive N₂O fluxes	(df=198)			(df=71)		
Null model	-530.07	0.00*	0.999*	-67.56	0.00*	0.997*
Partial <i>in-situ</i> production	-514.27	66.14	0.000	-54.63	12.93	0.002
Full <i>in-situ</i> production	-463.93	66.14	0.000	-30.92	36.64	0.000
Partial <i>in-situ</i> respiration	-514.81	15.26	0.001	-54.19	13.37	0.001
Full <i>in-situ</i> respiration	-475.58	54.49	0.000	-31.71	35.84	0.000

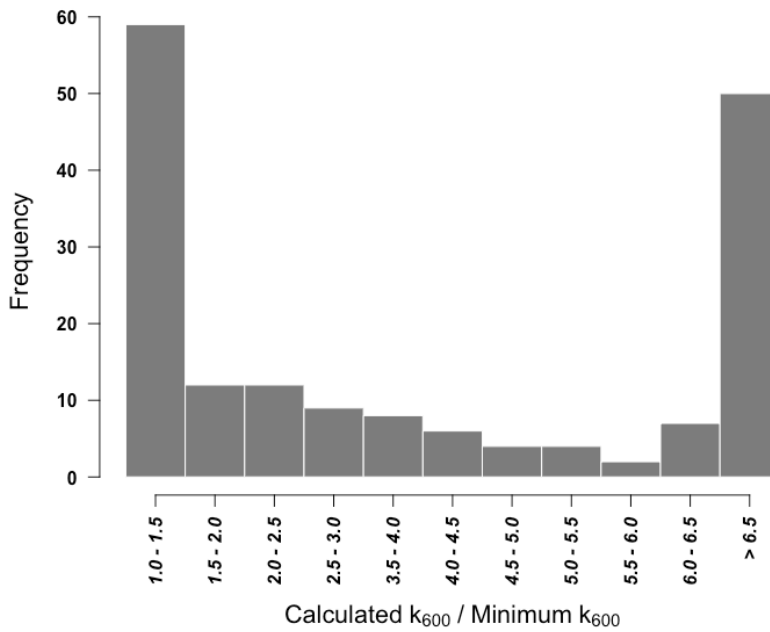


Figure S1. Frequency distribution of calculated k_{600} :minimum k_{600} in floating chambers.

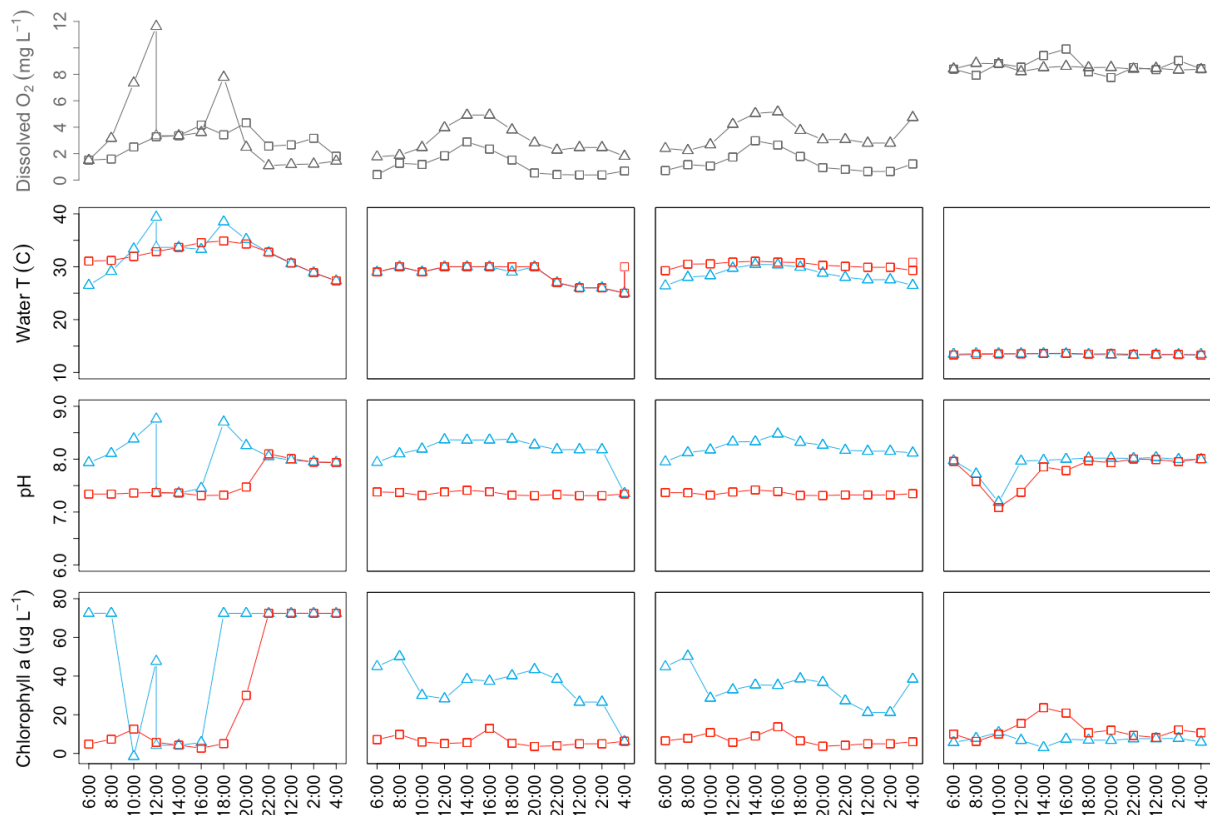


Figure S2. Diel variation in dissolved O₂ in natural and aquaculture ponds during each sampling event, compared with diel variation in water temperature, pH, and chlorophyll *a*, which were fixed effects in the linear mixed effects models.