Phosphorus Release from Lake Champlain Sediments under Oxidizing and Reducing Conditions

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Background

Legacy phosphorus (P) in lake sediments can contribute to soluble P release and P loading to the water column. Missisquoi Bay is a shallow, northern bay of Lake Champlain with a history of nuisance blue-green algae blooms. We quantified P release from intact sediment cores as part of a mass balance modeling study to quantify P loading from bay sediments.

Objective

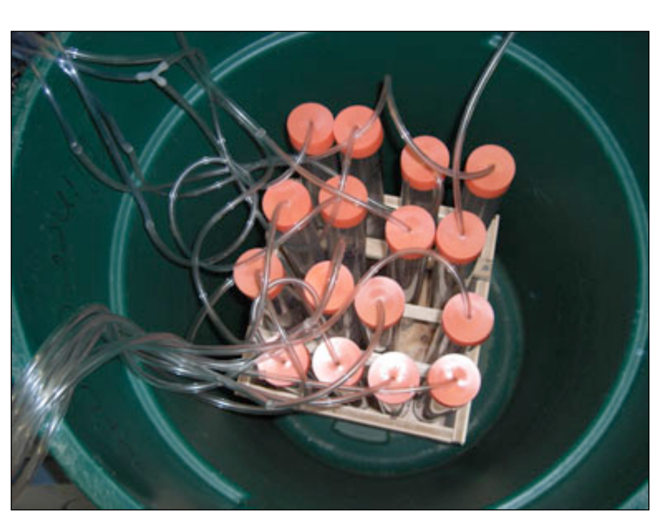
Determine rates and extent of total P (TP), soluble reactive P (SRP), and unreactive P (URP) release from sediments to overlying water under oxidizing and reducing conditions.

Materials and Methods

• Duplicate sediment cores (50 cm, 5 cm i.d.) were collected (Wildco Ogeechee sampler) at 4 locations on 9/9/10 (Fig. 1).

• Cores were transferred to acrylic vessels modified for equilibration of overlying water with either N_2 or O_2 gas.

• Microcosms were inundated with lake water. TP, SRP, and URP in overlying water were measured over a 15-day period at 20ºC in the laboratory.



• SRP (orthophosphate) was measured by molybdate colorimetry after filtration (<0.45 μm). TP was also measured colorimetrically after persulfate oxidation. URP was estimated by TP – SRP.

• Cubic regressions were performed on release data and equations were integrated to estimate cumulative P mass released.

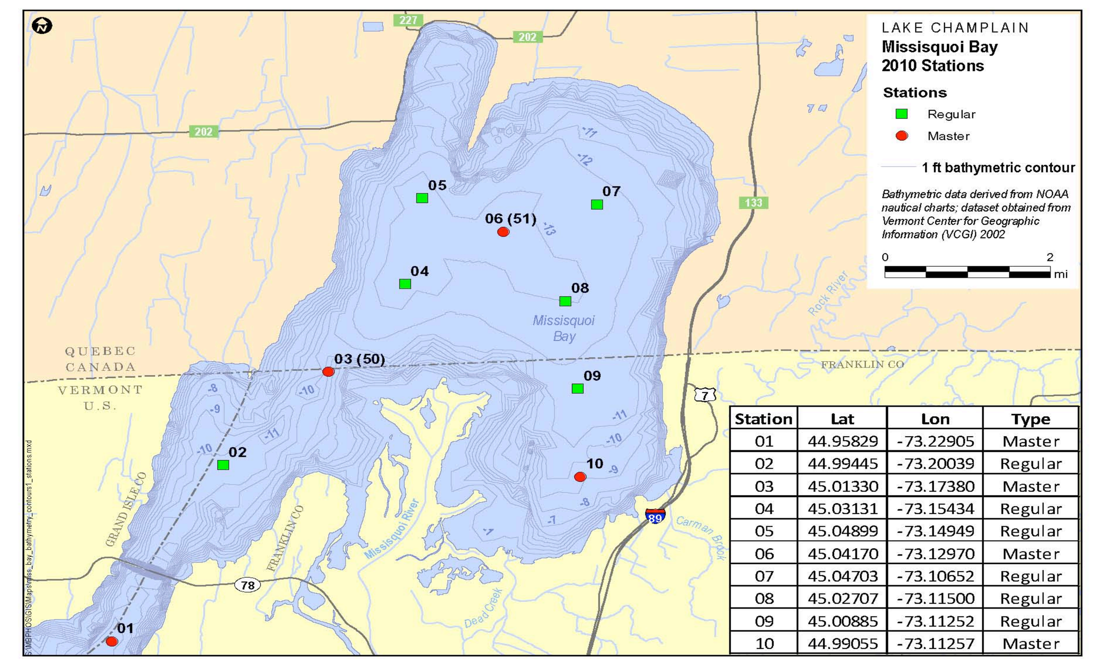


Figure 1. Bathymetric map of Missisquoi Bay, Lake Champlain showing sediment core sampling locations used for the study.

Results and Discussion

• Sediment pH, organic matter content, and extractable P (Modified Morgan) ranged from 5.3 to 5.8; 21 to 32 g kg^{-1}, and 3.5 to 5.0 mg kg^{-1}, respectively.

• TP and SRP were low at the start of the incubation (12 and 4 μg L^{-1}) and showed curvilinear increases with time (Fig. 2).

• Mean TP at day-15 for reduced and oxidized cores was 293 ± 19 and 106 ± 11 μg L^{-1}, respectively. Mean SRP was 137 ± 41 and 20 ± 8 μg L^{-1} at day-15, respectively.

• Reduced cores released 2.6,10.2, and 1.8-fold greater cumulative TP, SRP, and URP than oxidized cores (Figs. 2, 3; Table 1).

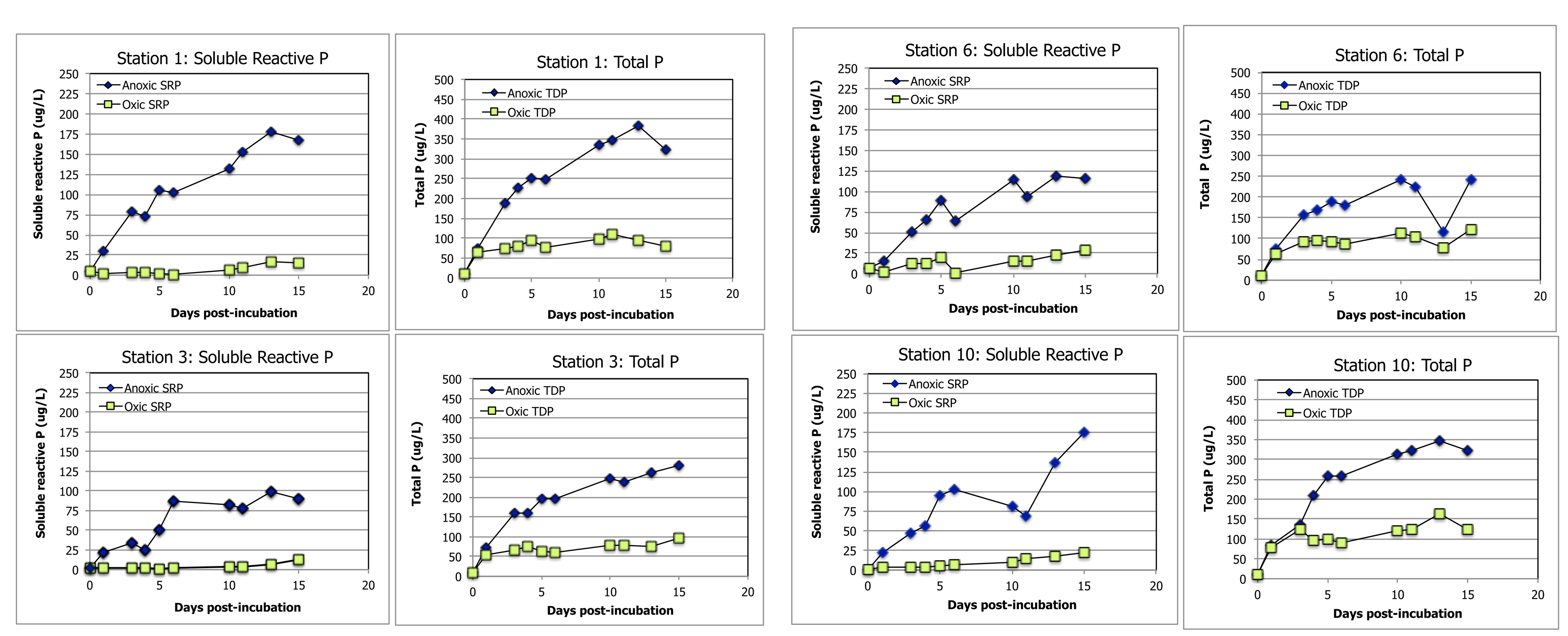


Figure 2. Total and soluble reactive P release in oxidized and reduced cores over the 15-day period.

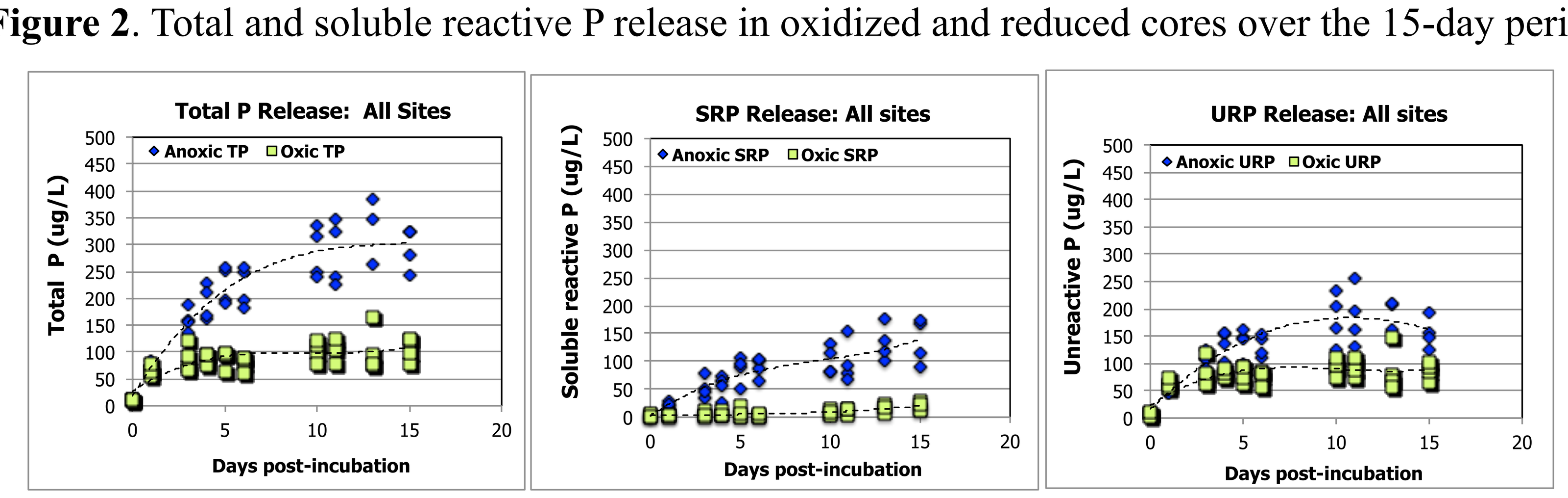


Figure 3. Total P, SRP, and URP release over 15-day period pooled across sediment sampling sites.

Table 1. Cubic regression equations describing TP, SRP, and URP release under reduced and oxidized conditions, model R^2, total P mass released, and ratio of P released under reducing to oxidized conditions.

Redox status	Phosphorus form	P release prediction equation	Model R^2	P mass released (μg)	Anoxic P mass/oxic	Mean release rate (μg P d^{-1})
Reduced	Total P	$y = 0.0901x^3 - 3.8408x^2 + 56.313x + 18.417$	0.88	3431		229
Oxidized	Total P	$y = 0.0823x^3 - 2.4073x^2 + 23.096x + 26.63$	0.60	1331	2.6	89
Reduced	SRP	$y = 0.068x^3 - 1.9037x^2 + 22.442x + 2.1782$	0.76	1276		85
Oxidized	SRP	$y = 0.0055x^3 - 0.0297x^2 + 0.3233x + 3.4905$	0.55	125	10.2	8
Reduced	URP	$y = 0.0228x^3 - 1.9554x^2 + 33.961x + 16.177$	0.80	2152		143
Oxidized	URP	$y = 0.0768x^3 - 2.3776x^2 + 22.773x + 23.139$	0.57	1206	1.8	80

• 61 and 91% of released P was URP (presumed to be organic) for reduced and oxidized cores, respectively (Table 1; Fig. 3).

• 37% of released P in anoxic cores was SRP vs. 9% in oxidized.

• Fe-P and/or Mn-P forms likely contributed to greater SRP and URP release in reduced cores.

Conclusions

• Released P was overwhelmingly organic P (P_o) in both reduced and oxidized cores. Microbial-P and higher molecular weight P_o could be a source of or sink for SRP depending on redox status, microbial dynamics, and other environmental factors.

• Recent studies with Missisquoi Bay sediments show P_o turnover is an important seasonal P source coupled to redox cycles, some of which is bioavailable (Giles et al., 2015; Smith et al., 2011).

• Greater knowledge of redox cycles in relation to SRP, P_o release and bioavailability in Missisquoi Bay sediments will lead to strategies to better predict onset of SRP release and nuisance algae blooms.

References

Giles, C.D., L.G. Lee, B.J. Cade-Menun, J.E. Hill, P.D. F. Isles, A.W. Schroth, and G.K. Druschel. 2015. Characterization of organic phosphorus forms and bioavailability in lake sediments using P nuclear magnetic resonance and enzymatic hydrolysis. J. Environ. Qual. 44:882-894.

Smith, L.G., M.C. Watzin, and G. Druschel. 2011. Relating sediment phosphorus mobility to seasonal and diel redox fluctuations at the sediment–water interface in a eutrophic freshwater lake. Limnol. Oceanogr. 56:2251–2264.