Relation of phosphorus release and sediment oxygen uptake to sediment characteristics in Big Platte Lake, Benzie Co., MI

2004 progress report

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Objectives

The overall objective of this study has been to better characterize the sediment throughout Platte Lake and to determine the magnitude of internal phosphorus release. The main goal has been to examine the effect of seasonal variation in hypolimnetic oxygen concentrations on sediment phosphorus release. In order to thoroughly describe the sediment throughout Platte Lake and to accurately compare Platte Lake to other lakes in similar studies, % water, % volatile solids, total sediment phosphorus (mg/g dry), and sediment oxygen uptake (g O^2/m^2/day) have also been measured. Thus, sediment oxygen uptake along with other sediment parameters should help to better understand oxic/anoxic phosphorus release in Platte Lake.

Methods

Beginning in February 2004, sediment samples were collected from Platte Lake on six dates for analysis of phosphorus release and/or sediment oxygen uptake. Eight sites were initially chosen in Platte Lake, and sediment oxygen uptake and phosphorus release were separately determined from sediment cores collected from different depths. Early in the study, sediment oxygen uptake was measured in all eight sites per sampling date, and phosphorus release was measured in four of the eight sites per sampling date to allow for one oxic and one anoxic core per site. However, to maximize the number of replicate samples per site, the original eight sites were reduced to four sites based on initial phosphorus release and sediment oxygen uptake rates as well as variation in water depth between sites. In addition, for the last 2004 sampling date (11/14/04), sediment oxygen uptake and anoxic phosphorus release were determined from separate cores collected on the same date. The determination of oxic phosphorus release rates was not conducted on 11/14/04 due to seasonal/time constraints.

Grab samples were collected on the same dates as phosphorus release core samples using a Ponar dredge. Grab samples were taken to determine physical and chemical characteristics of the sediment (% water, % volatile solids, and total phosphorus).

2004 Provisional Results

Sediment characteristics in Platte Lake (% water, % volatile solids, and total sediment phosphorus) were determined for 8 locations from grab samples collected on 4 dates (*Table 1*). Overall, % water and total sediment phosphorus were highest in samples collected from site T1-28. For site T1-28, the highest total sediment phosphorus concentration (0.371 mg/g) and the highest water content (79.86%) were measured in the sample collected on 8/10/04. However, site T2-22 yielded the three highest values of % volatile solids, with the sample collected on 11/14/04 producing the greatest volatile solids (14.10%). The lowest total sediment phosphorus value (0.056 mg/g) was found at site T3-2 on 5/17/04, whereas the lowest water content (47.03%) and the lowest volatile solids (3.72%) were from site T3-5 on 6/9/04 (*Table 1*). Site T3-10 yielded a relatively high water content (75.53%) and high volatile solids (13.19%), which were similar to repeated measurements of volatile solids and of water content from site T2-22.

Sediment oxygen uptake was compared for 8 locations in sediment cores collected on 3 dates (*Figure 1*). Site T1-5 yielded the lowest oxygen uptake rate (0.60 g O^2/m^2/day on 11/14/04), and site T1-28 produced the highest uptake rate (3.07 g O^2/m^2/day on 8/25/04). Two other sediment cores also yielded uptake rates of greater than 2 g O^2/m^2/day (2.50 g O^2/m^2/day for T2-22 on 8/25/04; 2.66 g O^2/m^2/day for T3-2 on 6/30/04). The overall highest oxygen uptake rates were measured in the cores collected on 8/25/04. Of the sites that were monitored on more than one date, sites T1-28 and T2-22 had the overall highest oxygen uptake rates.

Oxic and anoxic phosphorus release rates were measured in sediment cores collected from 8 locations in 2004. Four phosphorus release runs were conducted, and both positive and negative phosphorus release rates were observed. For the first phosphorus release run (*Figure 2)*, only one core yielded a positive phosphorus release rate (anoxic core from site T1-12), and the phosphorus release (3 µg P/m^2/day) was comparatively insignificant. The remaining seven cores collected on 5-17-04 showed an uptake of phosphorus (negative release rate). Anoxic phosphorus uptake was greater than oxic uptake for sites T2-22 and T2-5; oxic uptake was greater for sites T1-12 and T3-2 (*Figure 2).* For the second phosphorus release run (*Figure 3)*, two anoxic cores showed positive phosphorus release rates (865 µg P/m^2/day for T1-28; 474 µg P/m^2/day for T3-5). The other five cores, including all four oxic cores, from 6-9-04 yielded negative release rates (*Figure 3)*. Unlike the previous phosphorus release runs, the third

phosphorus release run (8/10/04) produced all positive release rates in both oxic and anoxic treatments (*Figure 4)*. Site T1-28 again showed the greatest anoxic phosphorus release rate (1021 µg P/m^2/day). In comparison to anoxic phosphorus release at each site on 8/10/04, oxic phosphorus release at each site was slightly reduced, with the exception of site T1-28 (*Figure 4)*. For the last phosphorus release run of 2004 (11/14/04), all anoxic release rates were positive (*Figure 5)*. The highest phosphorus release rate (1702 µg P/m^2/day) on 11/14/04 was again found in the anoxic core from site T1-28. On 11/14/04, site T3-5 yielded the second greatest release rate (1365 µg P/m^2/day), with sites T2-22 and T1-12 generating relatively less significant anoxic phosphorus release rates (*Figure 5)*. Considering only the sites sampled on multiple occasions, anoxic phosphorus release was highest for sites T1-28, T2-22, and T3-5 during the fall sampling period (11/14/04), while site T1-12 showed the greatest phosphorus release during the late summer sampling period (8/10/04).

Table 1: Sediment data of % water, % volatile solids, and total phosphorus (TP) are shown for 8 locations in Platte Lake. Grab samples were collected on 4 dates in 2004. Four sites were examined on each date. The water depth at each site can be identified by the second part of each site designation (i.e. T1-28 corresponds to a depth of 28 m).

	5/17/2004			6/9/2004			8/10/2004			11/14/2004		
Site	Water Content	Volatile Solids	TP (mg/g dry)	Water Content	Volatile Solids	TP (mg/g dry)	Water Content	Volatile Solids	TP (mg/g dry)	Water Content	Volatile Solids	TP (mg/g dry)
T1-28	---	---	---	79.18%	12.26%	0.364	77.98%	13.02%	0.371	79.86%	13.25%	0.359
T1-12	75.47%	9.70%	0.111	---	---	---	70.60%	8.54%	0.083	70.35%	9.70%	0.113
T1-5	---	---	---	54.36%	4.27%	0.061	---	---	---	---	---	---
T2-22	75.61%	13.67%	0.165	---	---	---	76.82%	13.77%	0.176	77.35%	14.10%	0.179
T2-5	53.46%	5.51%	0.106	---	---	---	---	---	---	---	---	---
T3-10	---	---	---	75.53%	13.19%	0.115	---	---	---	---	---	---
T3-5	---	---	---	47.03%	3.72%	0.103	50.12%	4.83%	0.087	54.70%	8.73%	0.114
T3-2	50.97%	4.00%	0.056	---	---	---	---	---	---	---	---	---

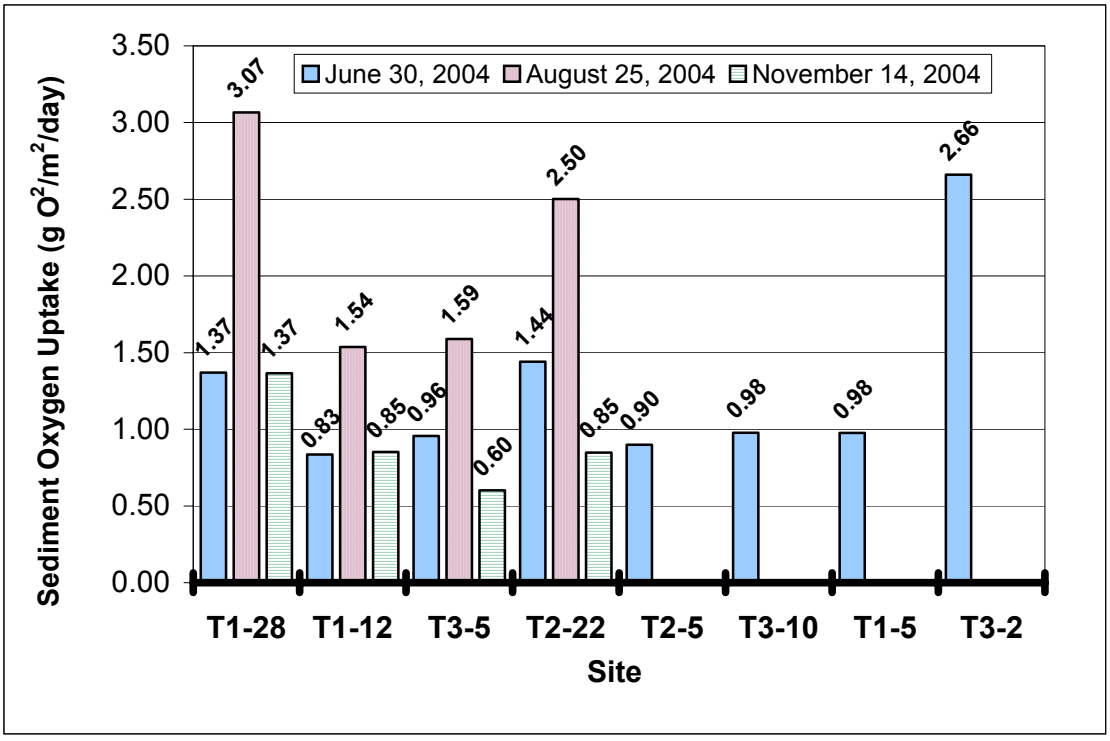


Figure 1: Comparison of sediment oxygen uptake rates among 8 sites in Platte Lake. Oxygen uptake rates were determined over an 8-hour period in sediment cores. Sediment cores were collected on 3 dates in 2004. All 8 sites were only sampled on one date (June 30, 2004).

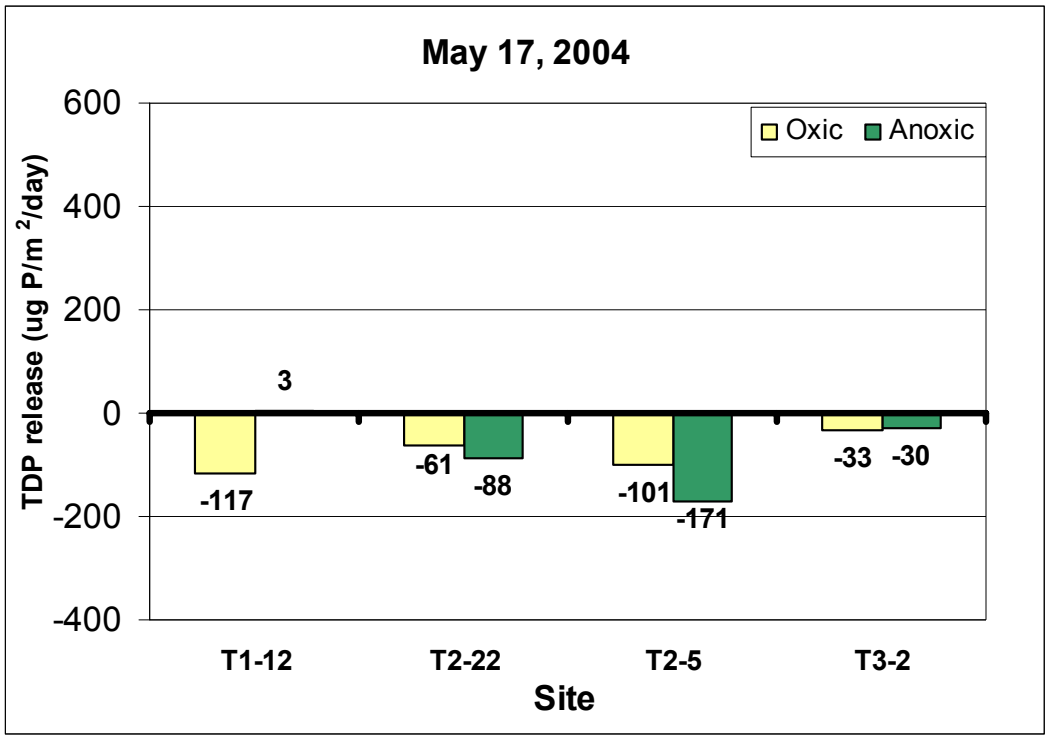


Figure 2: Comparison of oxic and anoxic total dissolved phosphorus (TDP) release rates among 4 sites in Platte Lake. Release rates were determined over a 10-day period from sediment cores taken on May 17, 2004. Negative values indicate an uptake of phosphorus.

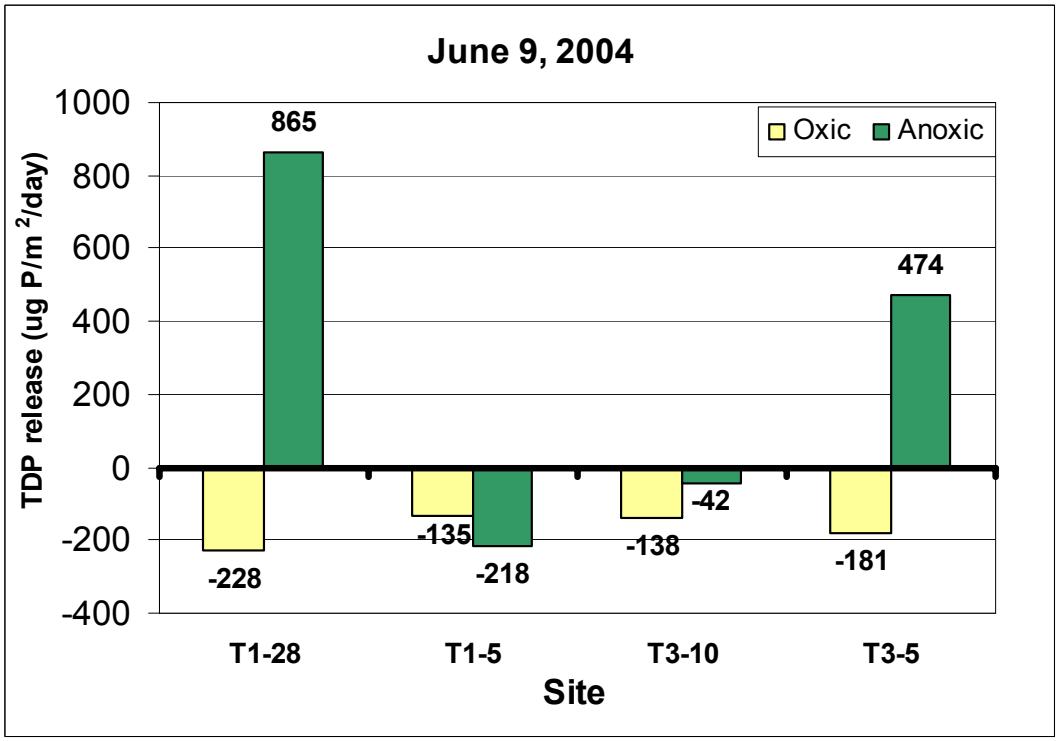


Figure 3: Comparison of oxic and anoxic total dissolved phosphorus (TDP) release rates among 4 sites in Platte Lake. Release rates were determined over a 10-day period from sediment cores taken on June 9, 2004. Negative values indicate an uptake of phosphorus.

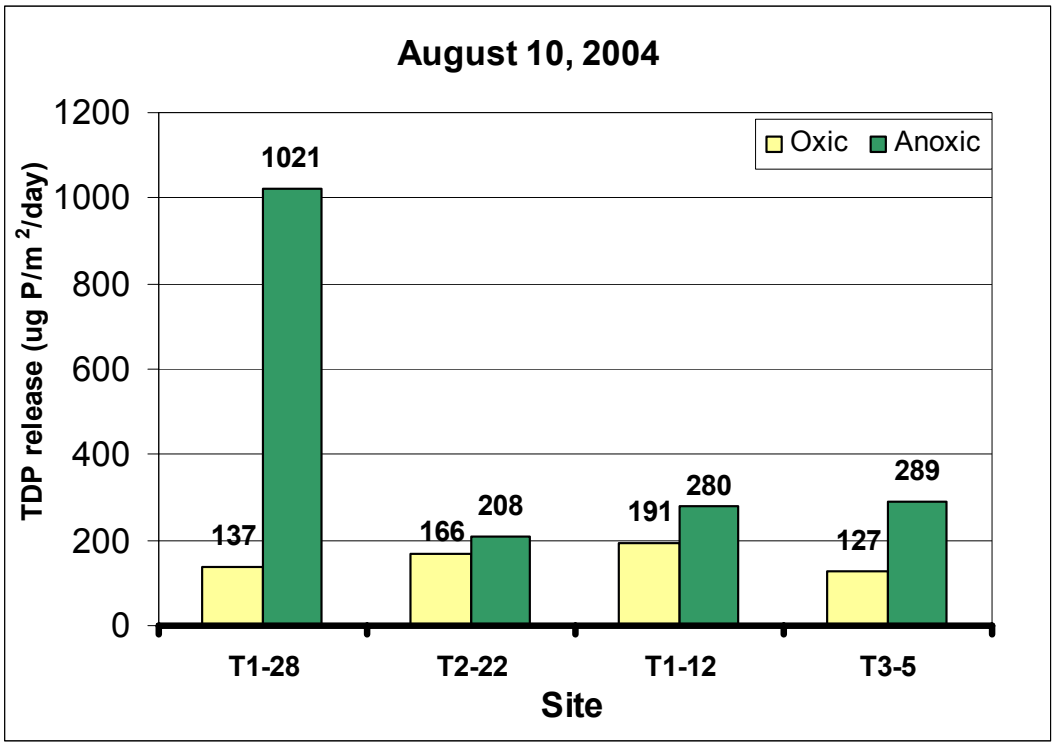


Figure 4: Comparison of oxic and anoxic total dissolved phosphorus (TDP) release rates among 4 sites in Platte Lake. Release rates were determined over a 10-day period from sediment cores taken on August 10, 2004. Negative values indicate an uptake of phosphorus.

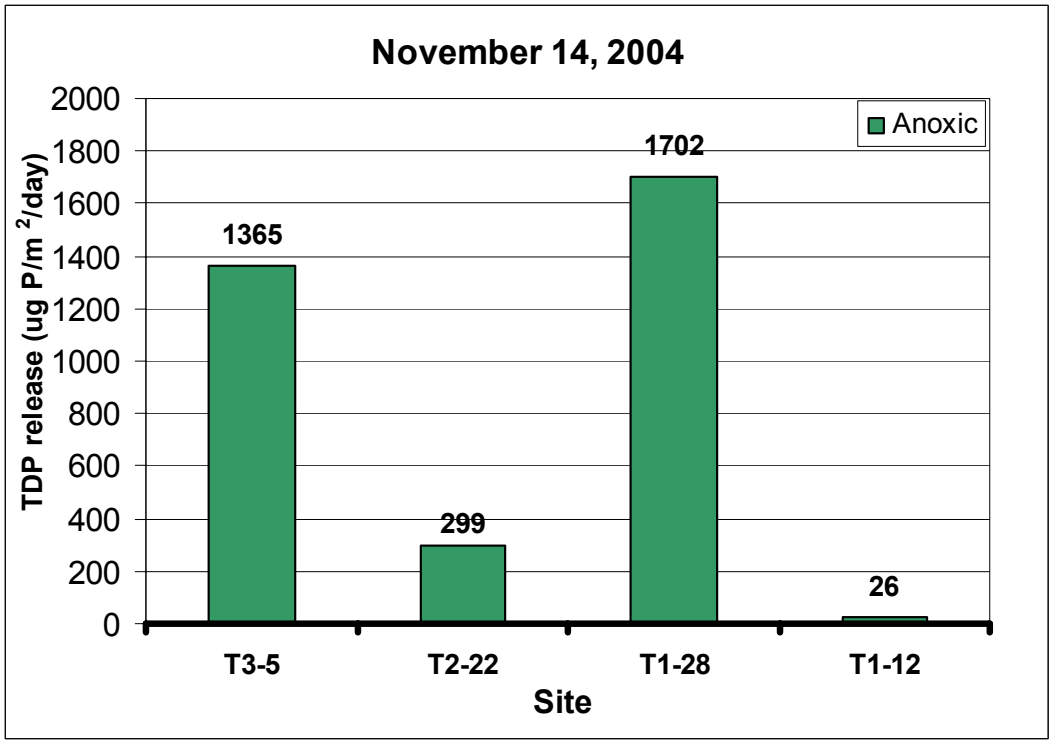


Figure 5: Comparison of anoxic total dissolved phosphorus (TDP) release rates among 4 sites in Platte Lake. Release rates were determined over a 10-day period from sediment cores taken on November 14, 2004. Negative values indicate an uptake of phosphorus.

Discussion

Variation in sediment characteristics between locations in Platte Lake is apparent, especially between shallow-water and deep-water locations. It was expected that total sediment phosphorus and % volatile solids would increase with depth in Platte Lake, and this prediction has generally held true over multiple sampling periods (*Table 1*). The deepest part of Platte Lake (T1-28) has repeatedly been found to contain the highest total sediment phosphorus, whereas the lowest total sediment phosphorus concentrations have mainly come from the shallowest sites (T3-2; T3-5; T1-5). As was seen for total sediment phosphorus, % volatile solids were lowest at the 2 m and 5 m sites. However, comparing % volatile solids between locations, it was unexpected that site T2-22 contained slightly higher % volatile solids than site T1-28. In addition, site T3-10 was shown to have a high % water and a high % volatile solids, which is surprising considering the low % water and low volatile solids content measured at similar depths, although the total sediment phosphorus concentration at site T3-10 was comparable to total sediment phosphorus at the other shallow water sites.

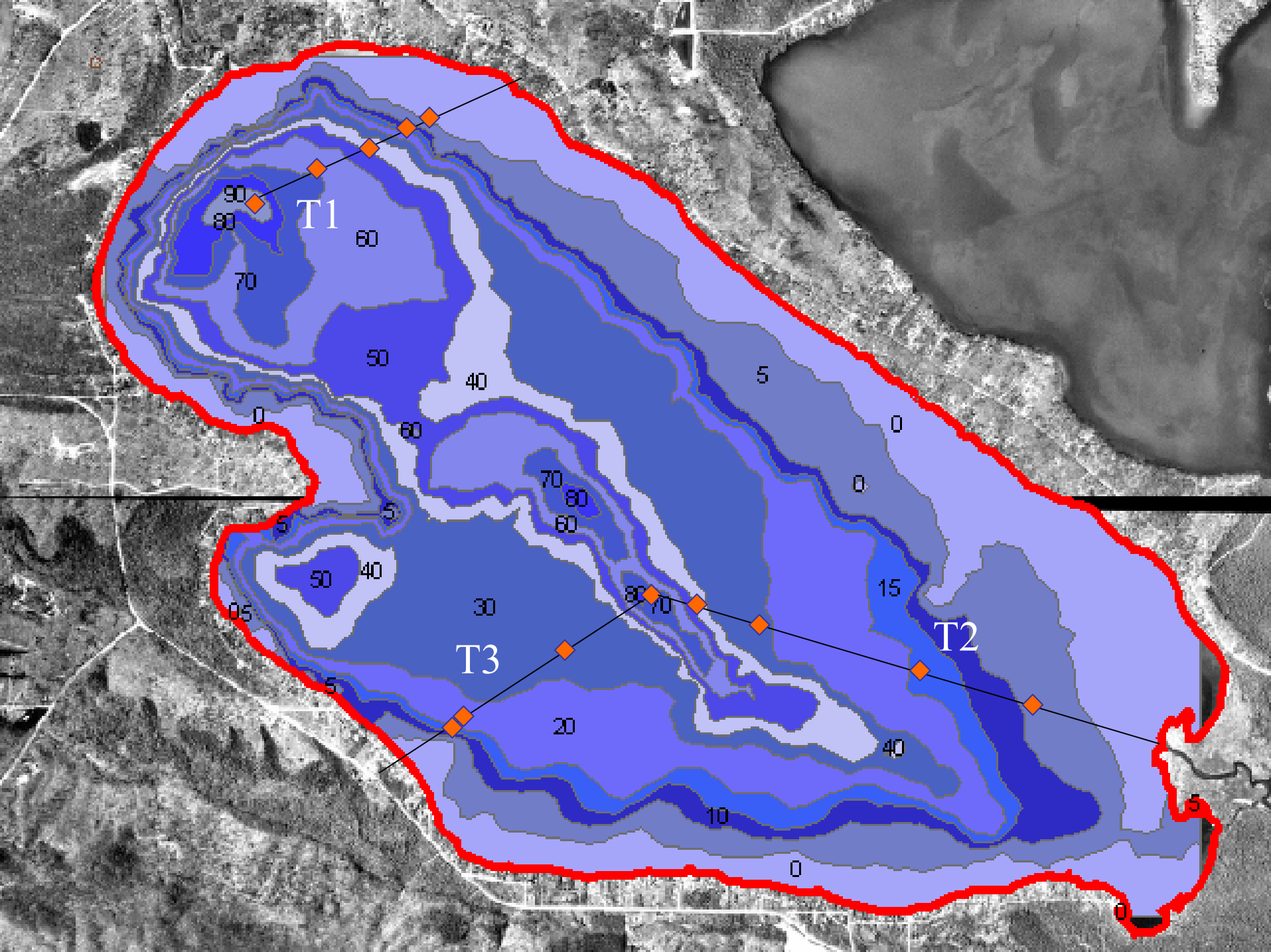
As predicted, sites T1-28 and T2-22 have shown high sediment oxygen uptake rates in comparison to other locations in Platte Lake (*Figure 2)*. The *in situ* duration of anoxia compared to the other sites along with high % volatile solids and high total phosphorus are likely interrelated with high sediment oxygen uptake. Furthermore, site T3-2 showing the highest sediment oxygen uptake on 6/30/04 was unanticipated. Given that site T3-2 has not been examined since 6/30/04, speculation on relative importance and any possible causes is difficult. In addition, the high sediment oxygen uptake rates at all four sites observed in the cores collected on 8/25/04 are likely explained by a combination of sustained low dissolved oxygen during summer stratification and of high organic matter accumulation by late summer. Dissolved oxygen in the hypolimnion of Platte Lake would be expected to be in the lowest concentrations during the end of the summer anoxic period, thus resulting in higher sediment oxygen uptake rates at this time.

As expected, anoxic sediment cores from site T1-28 have consistently shown the highest phosphorus release rates. The high anoxic phosphorus release rates from site T1-28 are likely related to the high volatile solids and high total sediment phosphorus. Additionally, anoxic phosphorus release rates from

T1-28 have progressively increased with each later sampling date in 2004. The greatest anoxic phosphorus release during the fall collection date may be attributed to an increased accumulation of detritus during early fall. Furthermore, the return of oxic conditions during fall turnover may have accelerated decomposition while simultaneously restricting sediment phosphorus release. If indeed this does occur in Platte Lake, application of anoxic conditions to sediment cores collected during late fall would therefore be expected to yield high anoxic phosphorus release rates. The negative phosphorus release rates seen mainly in oxic cores support the likelihood that high oxygen concentrations fix phosphorus in some sediments. Some possible explanations for the negative release rates may be attributed to biological assimilation of phosphorus or chemical adsorption during high oxygen conditions.

Sediment cores from sites other than T1-28 have also been shown to produce substantial anoxic phosphorus release rates (site T3-5 in *Figure 5*). However, under natural lake conditions, anoxic phosphorus release from shallow sites (i.e., T3-5) is not likely due to continued high oxygen levels. Thus, naturally sustained oxic conditions in the shallow-water areas of Platte Lake may be trapping releasable-phosphorus that would otherwise be recycled back into the water column during seasonal anoxic conditions. For the most part, with the exception of site T1-28, the other seven locations in Platte Lake to date have not shown substantial phosphorus release. Moreover, considering the high % volatile solids and the high sediment oxygen uptake of site T2-22, it is somewhat surprising that the phosphorus release rates of site T2-22 have been comparable to the release rates of the shallow-water sites. It may be possible that site T2-22 contains a high percentage of organically-bound phosphorus that is fixed in the sediment and not released during anoxia.

The characterization of the sediment including oxygen uptake and phosphorus release rates throughout Platte Lake has proceeded into 2005. Another sediment core collection for sediment oxygen uptake and anoxic phosphorus release analyses was conducted on 2/23/05, and an additional collection will likely take place by mid-summer of 2005. Furthermore, statistical analysis of data will provide essential information when sample collection has been fully completed.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