

**SEDIMENT NUTRIENT FLUX AND OXYGEN DEMAND STUDY FOR CANYON LAKE WITH  
NUTRIENT MONITORING AND ASSESSMENT OF IN-LAKE ALTERNATIVES:  
JANUARY – MARCH, 2007**

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### **Introduction**

This report summarizes the results from water column and sediment sampling conducted during the winter quarter 2007 to assess water quality and evaluate potential in-lake treatments to improve water quality in Canyon Lake.

### **Approach**

#### *Nutrient Monitoring*

Water column sampling during this reporting period was conducted monthly. As previously reported, field measurements included Hydrolab casts and water column sampling for a large number of constituents at 5 sites (M1, M2, M3, E1, and E2) on Canyon Lake (Fig. 1).



*Fig. 1. Canyon Lake sampling sites.*

#### *Sediment Nutrient Flux and In-Lake Treatment Evaluation*

Separate studies were also conducted to quantify the forms of phosphorus in the sediments, as well as the rate of internal recycling of nutrients. Sediments from the five

sites were extracted following Lewandowski et al. (2003) to quantify the concentrations of phosphorus in labile-, iron-, calcium-, aluminum- and organic-bound forms. The labile+Fe-P forms are generally considered potentially available for release, and are thus used to guide alum dose requirements. Sediment cores were also collected at the very end of the quarter to quantify winter nutrient flux rates as well as assess effects of aeration and oxygenation on rates of nutrient release. The nutrient analyses associated with these measurements were not available at the time of this report, and so will be discussed in the draft final report for this phase of the project to be completed later this month.

## Results

### *Temperature and Dissolved Oxygen*

The water column properties of the main body of Canyon Lake reversed the trends found in the previous reporting period. Cool, isothermal conditions continued into January, with water temperatures dropping to about 9 °C during an unusually cold interval in mid-January (Fig. 2a). The water column warmed in February with stratification present on the March 22<sup>nd</sup> sampling date following a period of very warm weather (Fig. 2a).

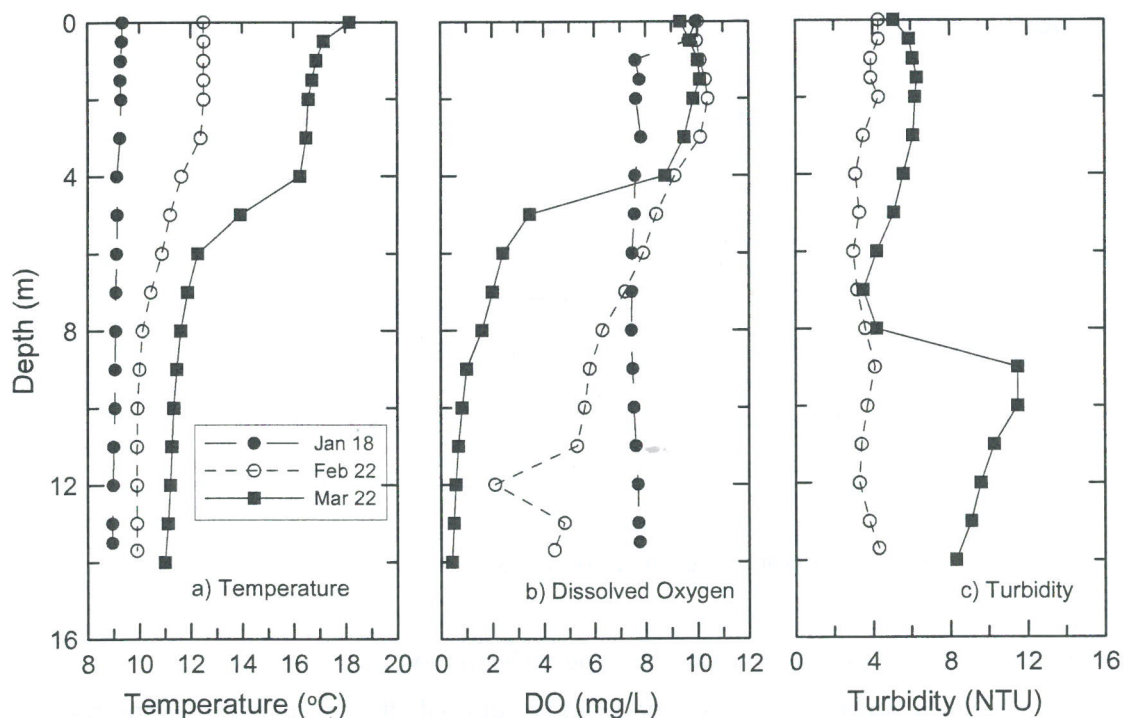


Fig. 2. Selected profiles from site M1: a) temperature, b) DO and c) turbidity.

The water column was well-mixed with respect to DO concentration on January 18<sup>th</sup>, with uniform concentrations of about 8 mg/L at all depths except the very surface where slightly higher concentrations were found (Fig. 2b). As the lake warmed however, (Fig. 2a), DO concentrations increased near the surface and declined lower in the water column, with anoxic conditions (DO <1.0 mg/L) already in place on the March 22<sup>nd</sup> sampling (Fig. 2b). The turbidity sensor on the Hydrolab was no functioning properly in the field on the January sampling date, so no data is available for that date. Turbidity averaged about 4 NTU throughout the water column in February, although turbidity levels increased from 4 NTU to 11 NTU below 8 m on the March 22<sup>nd</sup> sampling (Fig. 2c).

Conditions in East Bay mirrored those in the uppermost 3-4 m of the water column in the main body of the lake. Temperature, DO and turbidity were fairly uniform with depth (Fig. 3), with temperatures increasing from 9 °C to 18°C during this period. Dissolved oxygen concentrations varied from about 6-12 mg/L (Fig. 3b), reflecting higher daytime photosynthetic O<sub>2</sub> production later in the quarter. Turbidity levels increased from about 8 NTU found on February 22<sup>nd</sup> to about 15 NTU in March (Fig. 3c).

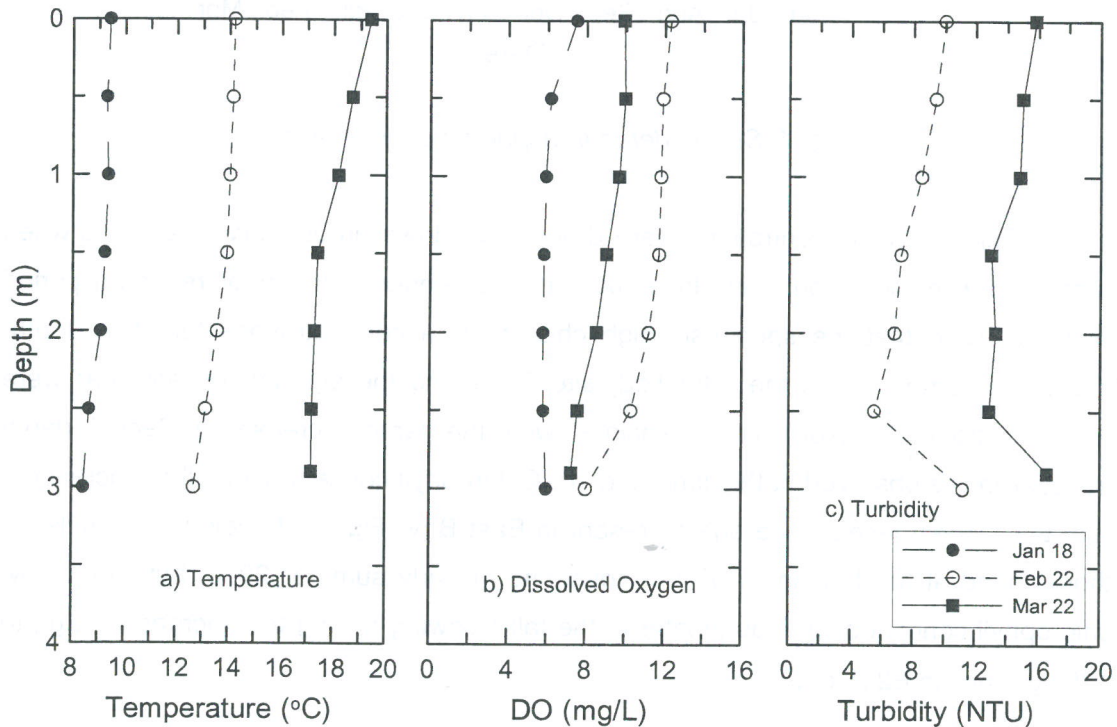


Fig. 3. Selected profiles from site E2: a) temperature, b) DO and c) turbidity.

### Transparency and Chlorophyll Concentrations

Transparencies measured with a Secchi disk increased dramatically at most sites in January, and then decreased to levels similar to those found in the fall (Fig. 4). Thus by March, Secchi disk depths ranged from 50 cm at site E2 to 75 cm at site M2. As has been found throughout most of the past 10 months, the lowest Secchi depth values were found at site E2, well into East Bay (Fig. 1).

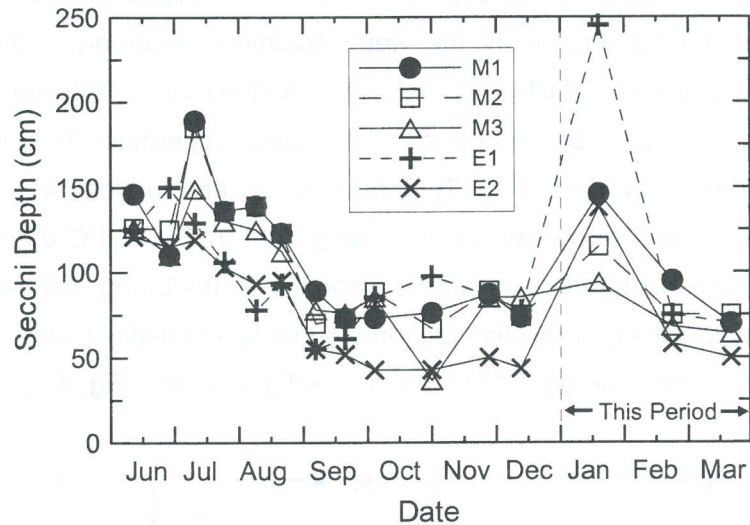


Fig. 4. Secchi depth transparencies over time.

Chlorophyll concentrations were dramatically lower in January at all sites when compared with those found in November and December of the prior reporting period (Fig. 5). (Note that the spuriously high chlorophyll a concentrations found in depth-integrated samples from the (stratified) site E1 during the summer of last year were removed from this plot.) This coincides with the large increase in Secchi depth transparencies observed at this time (Fig. 4). Chlorophyll concentrations then increased, with the highest levels once again present in East Bay (Fig. 5). Levels were similar to those found at the beginning of the monitoring in early summer 2006, but well below chlorophyll concentrations found later in the fall following mixing that increased, e.g., to 120  $\mu\text{g/L}$  at site E2 (Fig. 5).

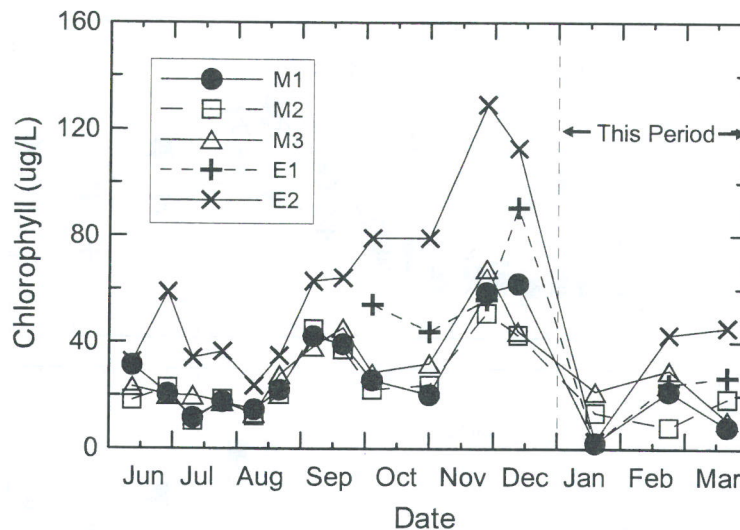


Fig. 5. Chlorophyll concentrations over time.

#### Nutrient Concentrations

Total P concentrations declined slightly from the values found in samples collected in November and December (Fig. 6). (Since the main body of the lake mixed earlier in November, depth-integrated samples were collected at all sites from November through March; for continuity, the depth-integrated concentrations for sites M1-M3 are also shown in plots for the thermocline and hypolimnion.) Notwithstanding, these total P concentrations are very high. Moreover, these concentrations are due principally to internal recycling of nutrients from the sediments, with the increases in the fall due to mixing of nutrient-rich hypolimnetic water into the upper water column (Fig. 6). The minimal rainfall this winter (<0.5 inches this calendar year) has contributed very little runoff to the lake and thus very little external loading of nutrients as well.

As previously noted, concentrations of soluble-reactive P (SRP) followed very closely observed trends in total P. SRP concentrations declined more substantially than total P in February, with readily available P in the East Bay sites declining to levels near or below 0.05 mg/L (Fig. 7). Concentrations increased at all sites in March however, with levels higher in the main body of the lake than in East Bay due to inclusion of some hypolimnetic water in the depth-integrated samples collected at that time.

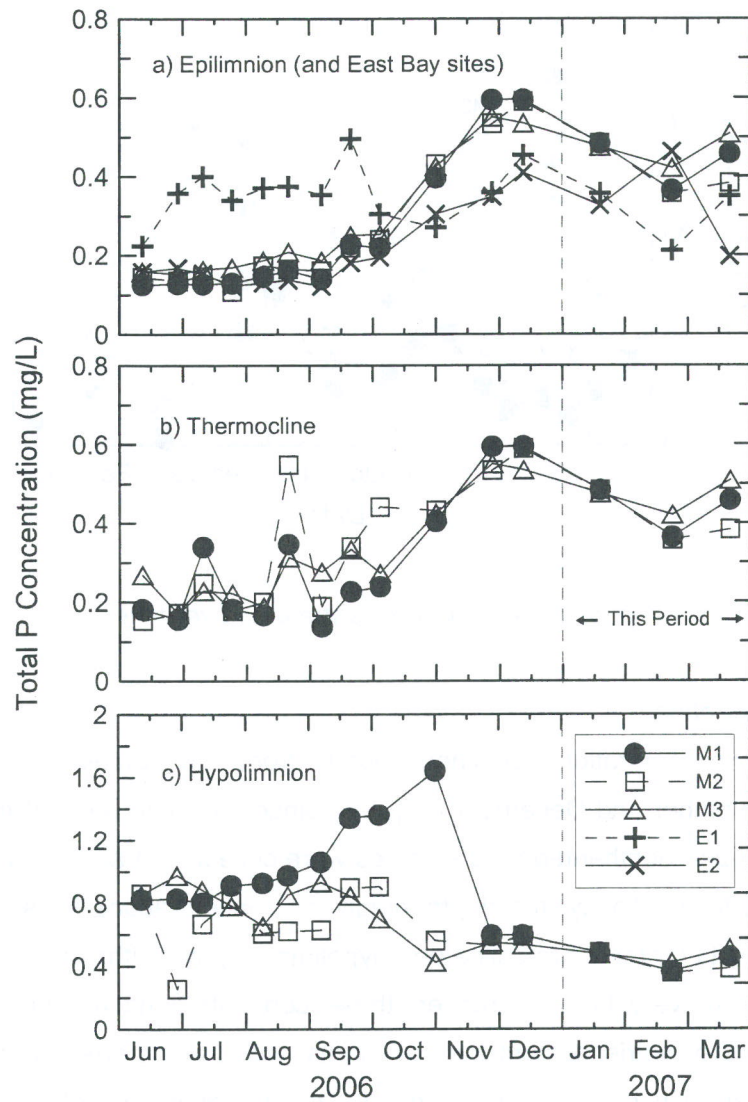


Fig. 6. Total P concentrations over time: a) epilimnion and East Bay sites, b) thermocline and c) hypolimnion. Thermocline and hypolimnion samples from the main lake sites only.

Total N concentrations in the main body of the lake decreased during this reporting period, from maximal values of about 1.4 mg/L in December to 0.8 – 1.0 mg/L (Fig. 8). Total N levels in East Bay reached higher levels in January before subsequently declining.

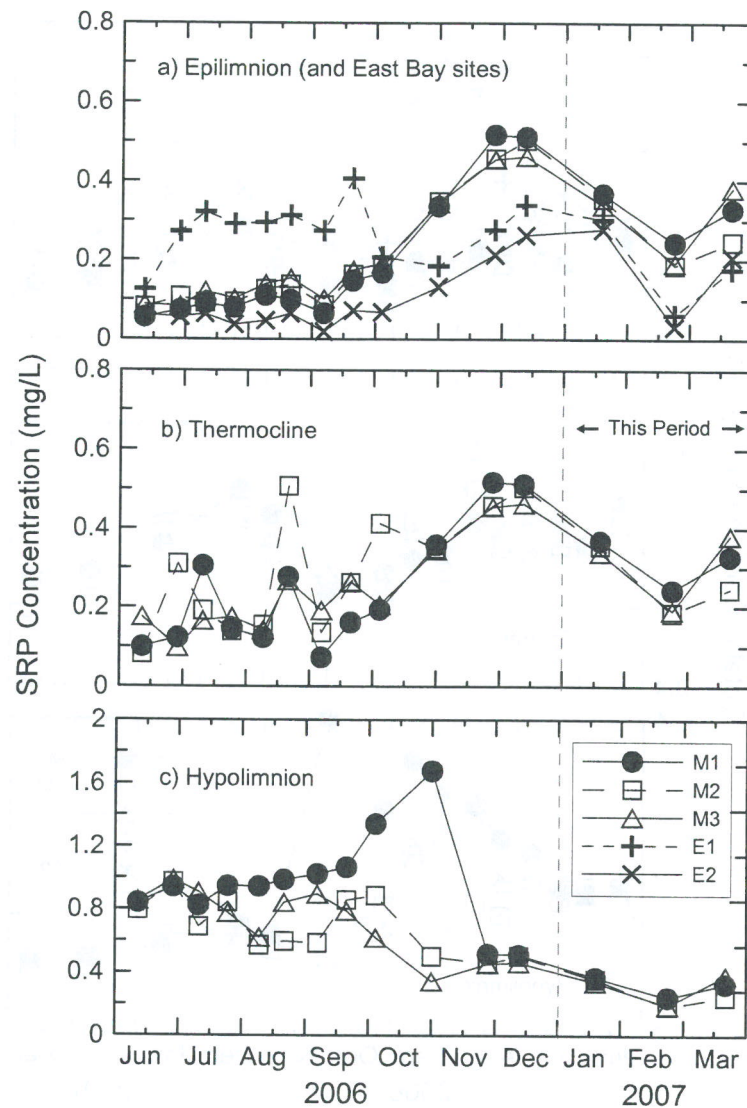


Fig. 7. SRP concentrations over time: a) epilimnion and East Bay sites, b) thermocline and c) hypolimnion. Thermocline and hypolimnion samples from the main lake sites only.

Ammonium-N levels in the lake declined more dramatically than total N from the levels found following turnover (Fig. 9). Concentrations as high as 0.95 mg/L were found in East Bay in January, while levels declined to <0.1 mg/L by March. Levels were somewhat higher at sites M1-M3, but the dramatic declines are attributed to increased phytoplankton production (Fig. 5). That is, maximum transparencies were associated with high levels of available  $\text{NH}_4\text{-N}$ , while the loss of  $\text{NH}_4\text{-N}$  (Fig. 9) was correlated with loss of transparency (Fig. 4) and increased chlorophyll concentrations (Fig. 5).

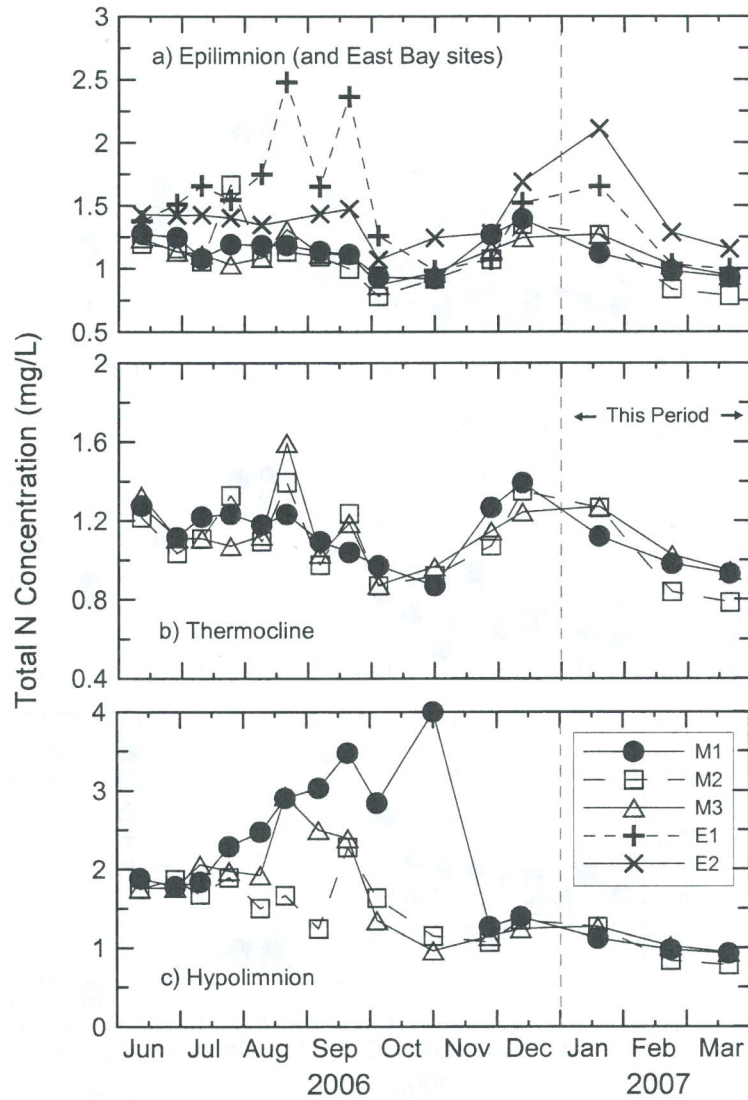


Fig. 8. Total N concentrations over time: a) epilimnion and East Bay sites, b) thermocline and c) hypolimnion. Thermocline and hypolimnion samples from the main lake sites only.

Concentrations of  $\text{NO}_3+\text{NO}_2\text{-N}$  have been below detection ( $<0.04$  mg/L) through all of last year, although measurable levels were found during this reporting period. Concentrations in the main body were 0.44-0.46 mg/L on January 18<sup>th</sup>, although levels declined to 0.31-0.34 mg/L on February 22<sup>nd</sup> and to  $<0.04$  mg/L by March 22<sup>nd</sup>. Slightly lower concentrations were found in East Bay in January (0.29-0.30 mg/L), although levels there also declined below detection by March. It thus appears that some limited runoff may have added nitrate to the lake, although it was quickly denitrified or used up by phytoplankton in this N-limited system.



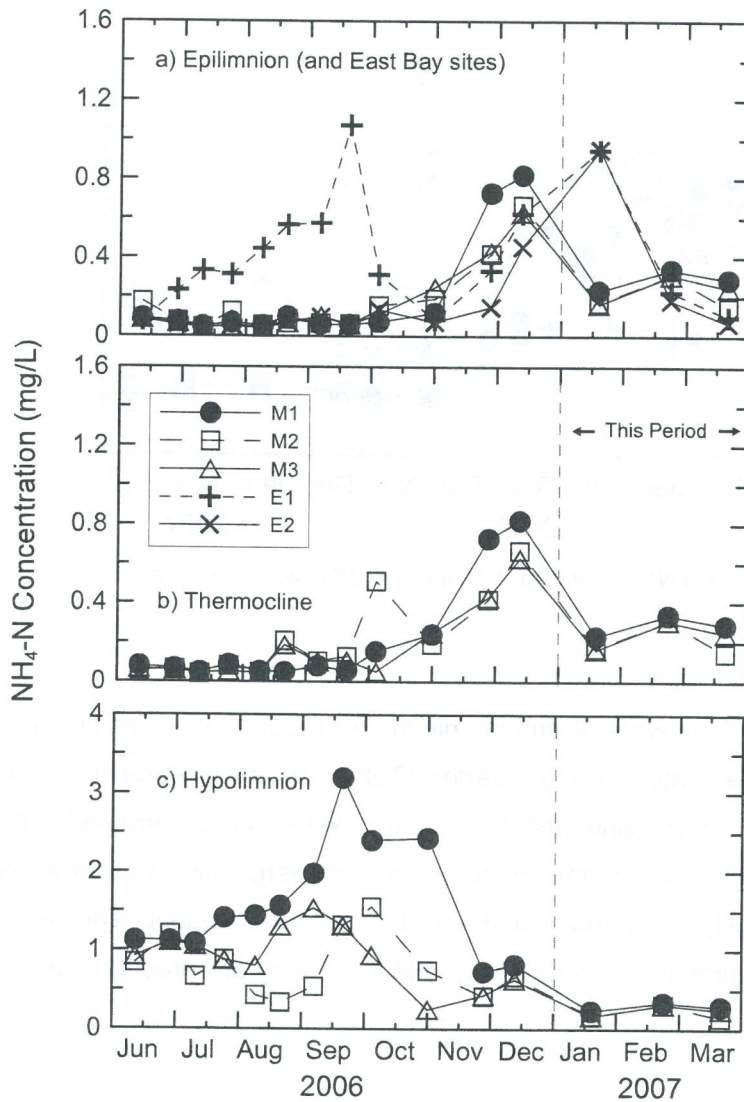


Fig. 9. Ammonium-N concentrations over time: a) epilimnion and East Bay sites, b) thermocline and c) hypolimnion. Thermocline and hypolimnion samples from the main lake sites only.

The total N:total P ratios confirm tendencies toward N-limitation, with TN:TP ratios declining to about 2 in the main body and 2-6 in East Bay (Fig. 10). These ratios are well below those found last summer, that were closer to the Redfield ratio and averaged about 8 in June-August (Fig. 10)

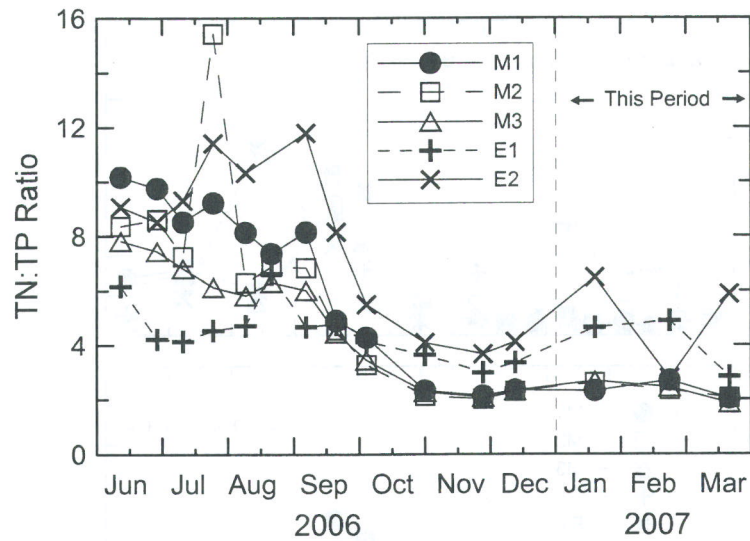


Fig. 10. TN:TP ratio of surface mixed layer samples.

#### Oxygen Demand

BOD concentrations were at annual minima for most of the sites in January, but increased quite marked later in the quarter (Table 3). As previously noted, BOD concentrations in the thermocline and hypolimnion were not determined (ND) since depth-integrated samples, rather than discrete samples, were collected for this period as a result of the generally isothermal, well-mixed conditions present. The lake will be sampled following the protocol for stratified conditions if they are present when sampled in April.

Site	Sample	9-Aug	6-Sep	31-Oct	27-Nov	12-Dec	18-Jan	22-Feb	22-Mar
<b>M1</b>	Epilimnion	6.4	4.9	0.3	2.8	2.8	1.9	2.3	2.1
	Thermocline	5.0	3.9	1.3	ND	ND	ND	ND	ND
	Hypolimnion	9.7	18.5	15.0	ND	ND	ND	ND	ND
<b>M2</b>	Epilimnion	6.6	3.9	2.3	2.0	2.0	2.8	3.6	3.4
	Thermocline	7.4	4.7	2.3	ND	ND	ND	ND	ND
	Hypolimnion	9.1	7.7	4.5	ND	ND	ND	ND	ND
<b>M3</b>	Epilimnion	7.8	4.0	2.3	2.5	2.5	2.8	3.9	3.8
	Thermocline	7.0	3.2	2.3	ND	ND	ND	ND	ND
	Hypolimnion	10.8	14.8	2.3	ND	ND	ND	ND	ND
<b>E1</b>	Depth-Integr	10.3	6.0	2.6	2.2	2.2	1.0	5.4	4.5
<b>E2</b>	Depth-Integr	8.8	4.4	5.0	4.5	4.5	1.3	6.1	6.7