1 Sedimentation

1.1 Objectives

In order to obtain data for fluxes of particulate and dissolved nutrients between the water phase and the sediment and to monitor sediment profiles of dissolved and particulate nutrients it was agreed to:

- Measure the primary settling of TPP, TPN, TPC and TBSi by exposure of sediment traps with the same spatial and temporal resolution as for water sampling

- Measure the net exchange PO4, NH3, NO3 and Si across the sediment water interface by laboratory experiments on undisturbed sediment cores with the same spatial and temporal resolution as for water sampling

- Measure the temporal variation in pore water profiles of PO4, NH3, NO3 and Si with the same resolution as for water sampling

- Measure the temporal variations in profiles of TPP, TPN, TPC and TBSi with the same spatial and temporal resolution as for water samples

1.2 Sediment processes

Particulate matter in lakes derives from import from the catchments and the atmosphere and from in-lake production. Particles are inorganic deriving from erosion in the catchments and in the lake or by chemical precipitation or they are organic particles produced by primary production and further metabolised through the food chains in the catchments and in the lake. Particles with a density higher than lake water settle to the sediment floor and can be captured by sediment traps. During settling the particles are mineralised and the primary settling flux decreases with the trap exposure depth. By reducing the exposure time to 1 - 2 days the mineralisation in the traps becomes negligible compared to the mineralisation during the settling. Close to the sediment floor the traps will also catch resuspended particles from the sediment dependent on the shear stress from waves and currents and the cohesive forces between the sediment particles.

In the sediment mineralisation continues and dissolved nutrients are released to the pore water and by control of sorption equilibriums and molecular diffusion along concentration gradients the dissolved nutrients can move upwards or downwards participating in further microbial processes like bacterial uptake, remineralisation, nitrification and denitrification. The relative importance of sedimentary processes compared to processes in the water phase increases with hydraulic residence time and decreases with water depth. L. Victoria has a long residence time - 100 years - and has a relatively low average depth - 40 m. Consequently, sedimentary processes become very important in Lake Victoria justifying the comprehensive sediment sub model as an important part of the Lake Victoria Model. Pore water concentrations, labile and stable particulate nutrient fractions and diffusive fluxes are state variables and processes constituting important parts of the sediment model.

Short term exposures of sediment traps at depths where resuspension is expected to be negligible and short term experimental determination of sediment-water fluxes at aerobic and anaerobic conditions are combinations of field and laboratory efforts to monitor the essentials of the sediment water interactions.

1.3 Methods

1.3.1 Sedimentation

Duplicate sediment traps with diameters from 4.5 cm to 8.4 cm and an aspect ratio >5 were mounted on an anchored rope kept vertical with a subsurface buoy and connected to a marking buoy. Three sets of traps were placed at each station:

- At the end of the photic zone (2.2 x secchi depth)
- 2 m above the sediment
- One set in between the two.

Initially, duplicate traps were exposed at depths 0.2, 0.4, 0.6 and 0,8 m above the bottom to determine the resuspension layer. After 1 - 2 days of exposure the traps were retrieved and the trapped particles were sub sampled and collected on GF-C glass fibre filters (pore size 1 um) to be analysed for TSS, TPP, TPN and TPC, and also collected on Nucleopore membrane filter (pore size 0.45 um) to be analysed for TBSi. The settling fluxes can then be calculated in $mg/m^2/d$ based on the trap area and exposure time and after correction for the particulate content initially in the water.

1.3.2 Flux experiments

Two undisturbed sediment cores (5 - 10 cm diameter, 20-30 cm length) taken by a gravity corer or sub-sampled from a dredge are incubated in a water bath thermostatted at ambient lake temperature. Over the first 24 hours the over-all oxygen consumption is recorded, and hereafter one core is bubbled with air and the other bubbled with nitrogen. Once per day over a 5-day period water samples are withdrawn and analysed for NH3, NO3, PO4 and Si. Knowing core area, water volume corrected for withdrawal and exposure time, the aerobic and anaerobic fluxes across the sediment-water interface can be calculated in mg/m^2/d.

1.3.3 Sediment profiles

Two undisturbed sediment cores (5 - 10 cm diameter, 20-30 cm length) taken by a gravity corer or sub sampled from a dredge are sectioned in slices: 0-1 cm, 1-2 cm, 2-3 cm, 3-5 cm and 5-10 cm. From one set of sediment slices pore water is retrieved by vacuum suction through a GF-C glass fibre filter (pore size 1 um) and immediately analysed for NH4, NO3, PO4 and Si. The slices from the other core are sub sampled and analysed for TSS, TPP, TPN, TPC and TBSi. Sediment concentrations are calculated in g/m^2 (0 - 10 cm) assuming densities of water and organic matter of 1 and a density of the ash of 2.6.

1.4 Results

1.4.1 Sampling statistics

The total number of successful deployments of sediment trap chains was 112 and the total sum of analyses carried out on the caught material was 670. Actually, more than the double of deployments took place, but the retrieval of deployed traps failed for a number of reasons:

- Drifting of traps due to unsafe mooring and strong winds
- Imprecise recording of mooring position
- Theft by fishermen or others

Theft was most likely the main reason for the disappearance of the traps

Table 1.1 Sampling frequency for sedimentation traps

	Kenya	Uganda	Tanzania	Total
Number of littoral stations	6	8	5	19
Number of pelagic stations	3	9	9	21
Total number of stations	**9**	**17**	**14**	**40**
Number of littoral deployments	14	29	10	53
Number of pelagic deployments	7	24	28	59
Total number of deployments	**21**	**53**	**38**	**112**
Settling of phosphorus	41	87	83	211
Settling of nitrogen	7	100	24	131
Settling of biogenic silicon	17	56	66	139
Settling of carbon	41	148	0	189
Total number of analyses	**106**	**391**	**173**	**670**

1.4.2 Resuspension

During the initial cruise in the Ugandan part of Lake Victoria a number of traps were exposed close to the bottom to provide indications of resuspension, see Figure 1.1

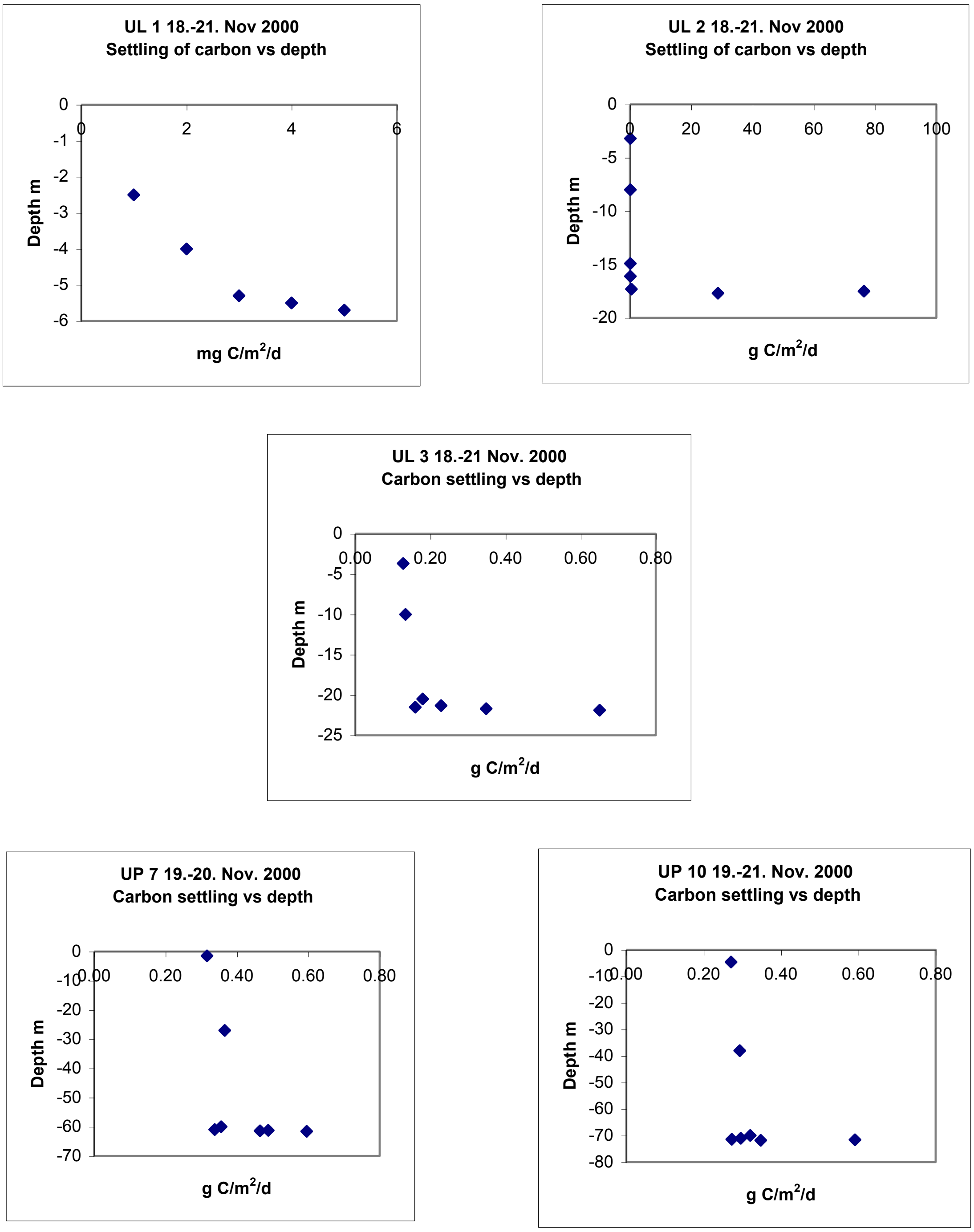

Figure 1.1 Vertical distribution of sedimentation rates

In all cases except the very shallow UL 1 (6 m depth) the increase in carbon sedimentation rate observed close to the bottom is restricted to the 1 m zone above the bottom and it can be concluded that resuspension is not interfering if traps are exposed from 2 m above the bottom and upwards.

1.4.3 Sedimentation rates

The average annual sedimentation rates and the number of deployments are shown for TPC, TPN, TPP and TBSi in Figure 1.2 to Figure 1.5.

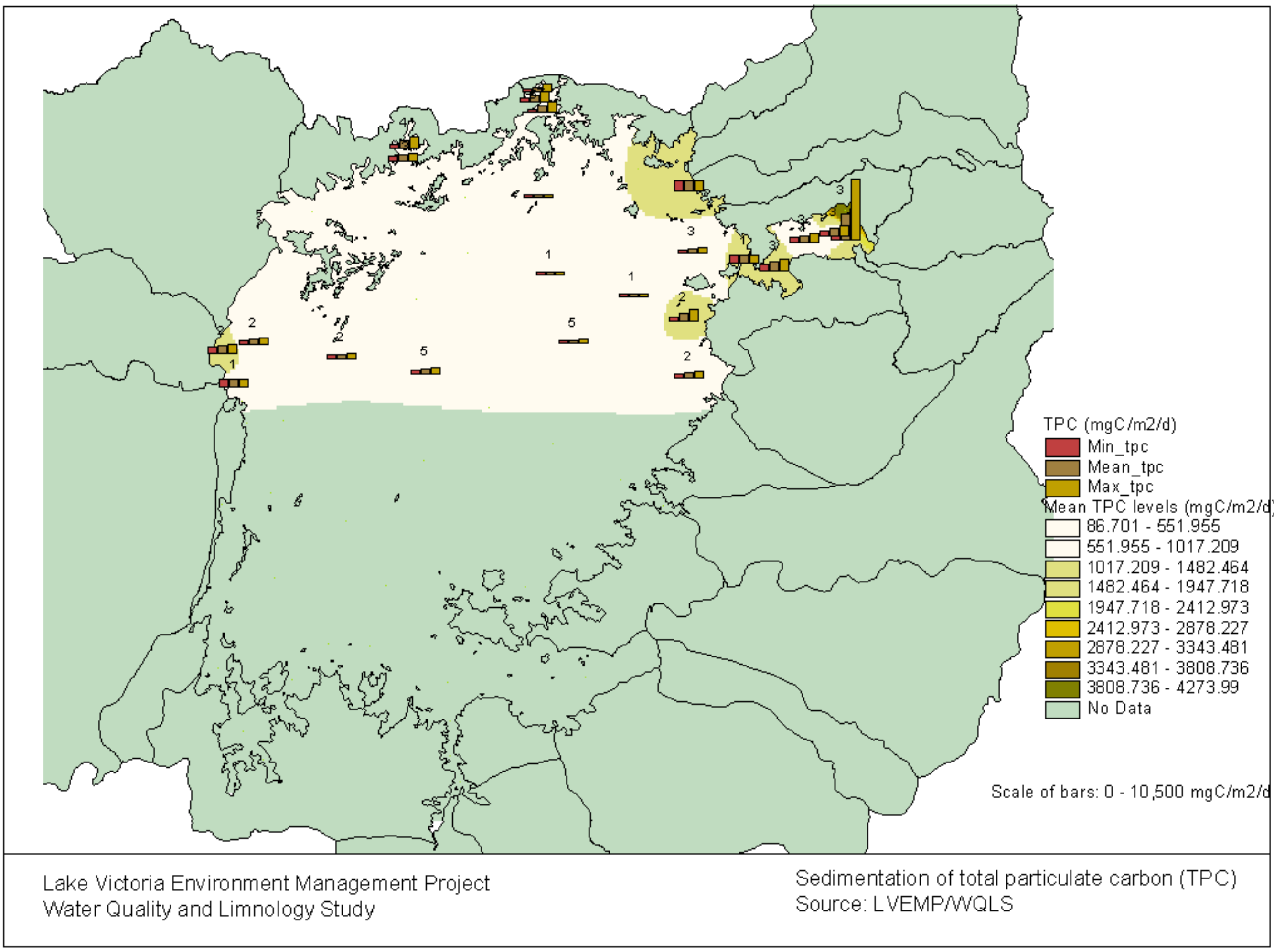

Figure 1.2 Distribution of average annual TPC sedimentation rates and sampling frequencies

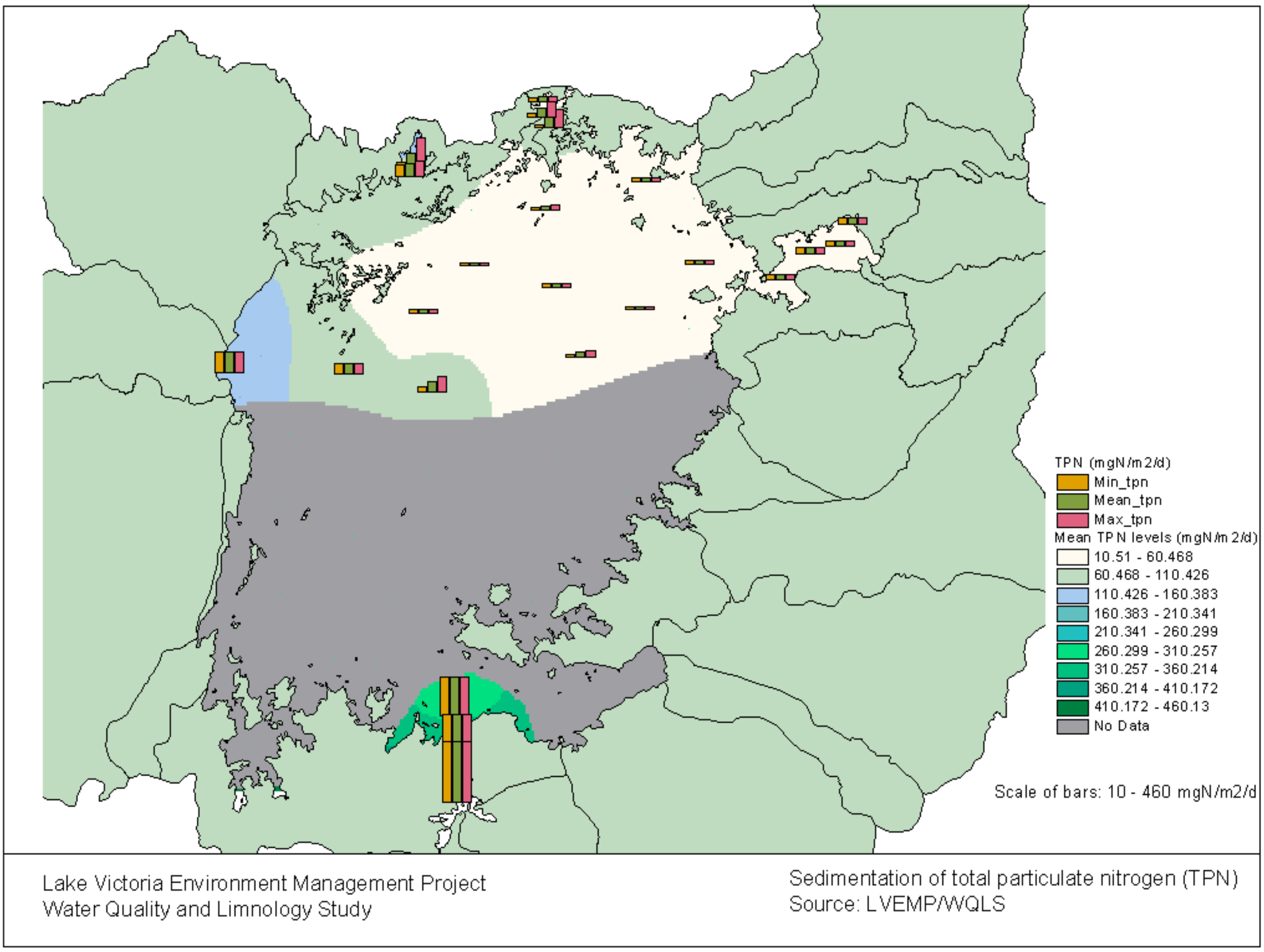

Figure 1.3 Distribution of average annual TPN sedimentation rates and sampling frequencies

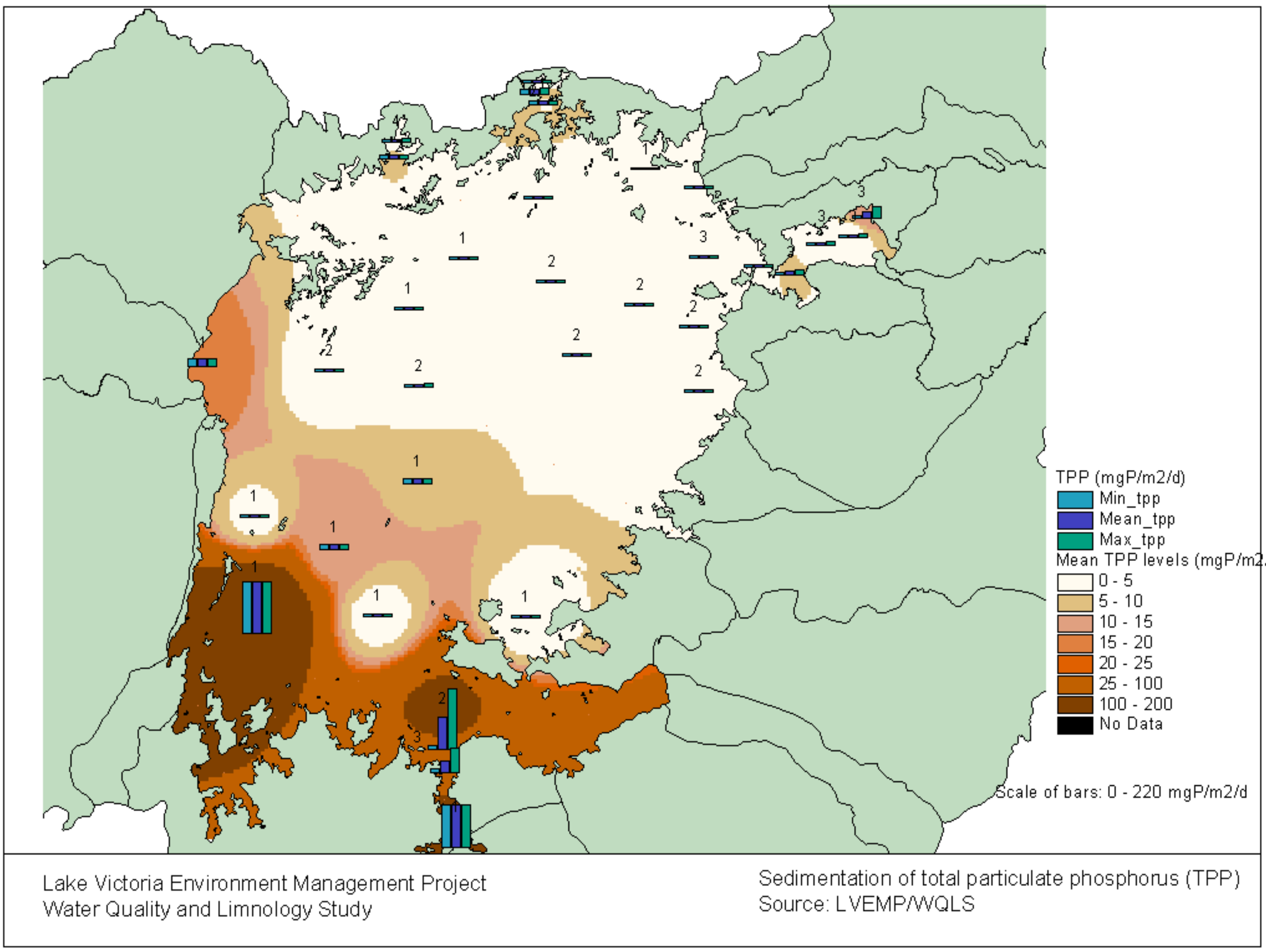

Figure 1.4 Distribution of average annual TPP sedimentation rates and sampling frequencies

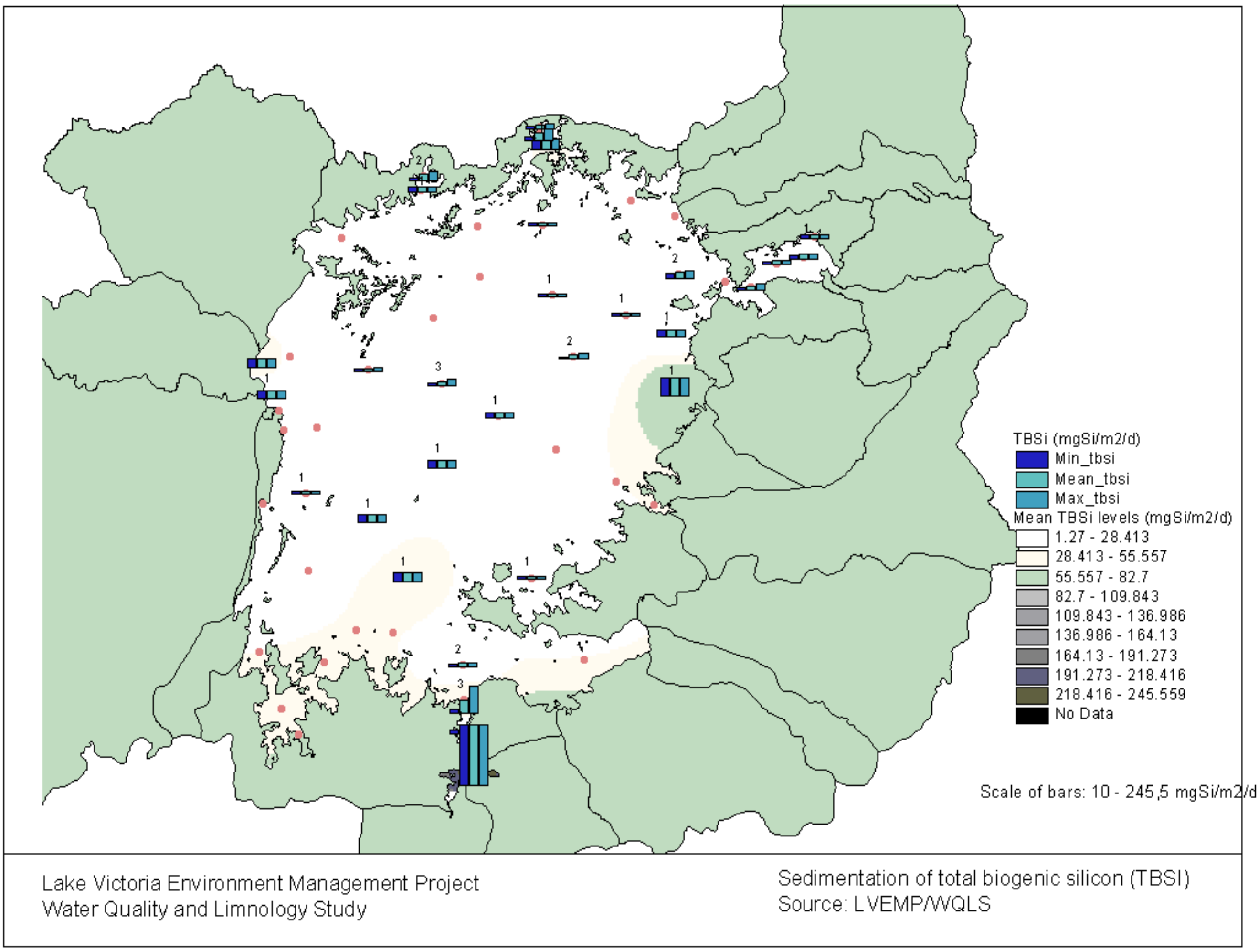

Figure 1.5 Distribution of average annual TBSi sedimentation rates and sampling frequencies

The daily average deposition rate for TPP, TPN, TBSi and TPC are listed in Table 1.2. For comparison the modelled data for TPP and TPN from off shore Entebbe at 42 m depth and from Gulf of Kisumu at 6 m depth (Kamp-Nielsen et al 1981) as well as calculations of burial of TPP by Hecky (1993), Holtzman and Lehman (1998) and for TBSi by Johnson et al. (1998) are also shown.

Table 1.2 Daily average deposition rate for TPP, TPN, TBSi and TPC

	TPP mg/m²/d	TPN mg/m²/d	TBSi mg/m²/d	TPC mg/m²/d
Settling rate LVEMP (2001) Total Littoral Pelagic	 20.78 24.23 17.75	 93.43 117.09 68.13	 29.18 41.76 17.92	 847.85 1123.91 379.75
Settling rate Kamp-Nielsen et.al. (1981) Entebbe 1978 Kisumu 1978	 8.00 30.00	 40.00 105.00		
Burial rate LVEMP (2001)	0.80 (3.8%)	8.00 (8.6%)		
Burial rate Hecky (1993)	0.49	3.90		
Burial rate Holtzman and Lehman (1998)	3.0			
Burial rate Johnson et.al. (1998)			3.01	
Release rate LVEMP (2001)	19.90	90.40		

The annual sedimentation rates are of the same order of magnitude as modelled for 1978 and the comparison with calculated net deposition rates shows that 4% of the sedimented phosphorus, 8 % of nitrogen and 10% of silicon is permanently buried.

The burial rates represent an annual accretion of 1 mm/year, so the lake is in no danger of being filled with sediment in the immediate future.

To describe the stochiometric composition of the settled material regressions were performed as shown in *Figure 1.6*.

Combining these regressions a stochiometric composition of the settling material can be written:

$$C_{100}N_{10.8}P_{0.9}Si_{4.9}$$

The stochiometry indicates nitrogen limitation and a phytoplankton community not dominated by diatoms in which Si constitutes 50% of the dry weight (Reynolds 1984).

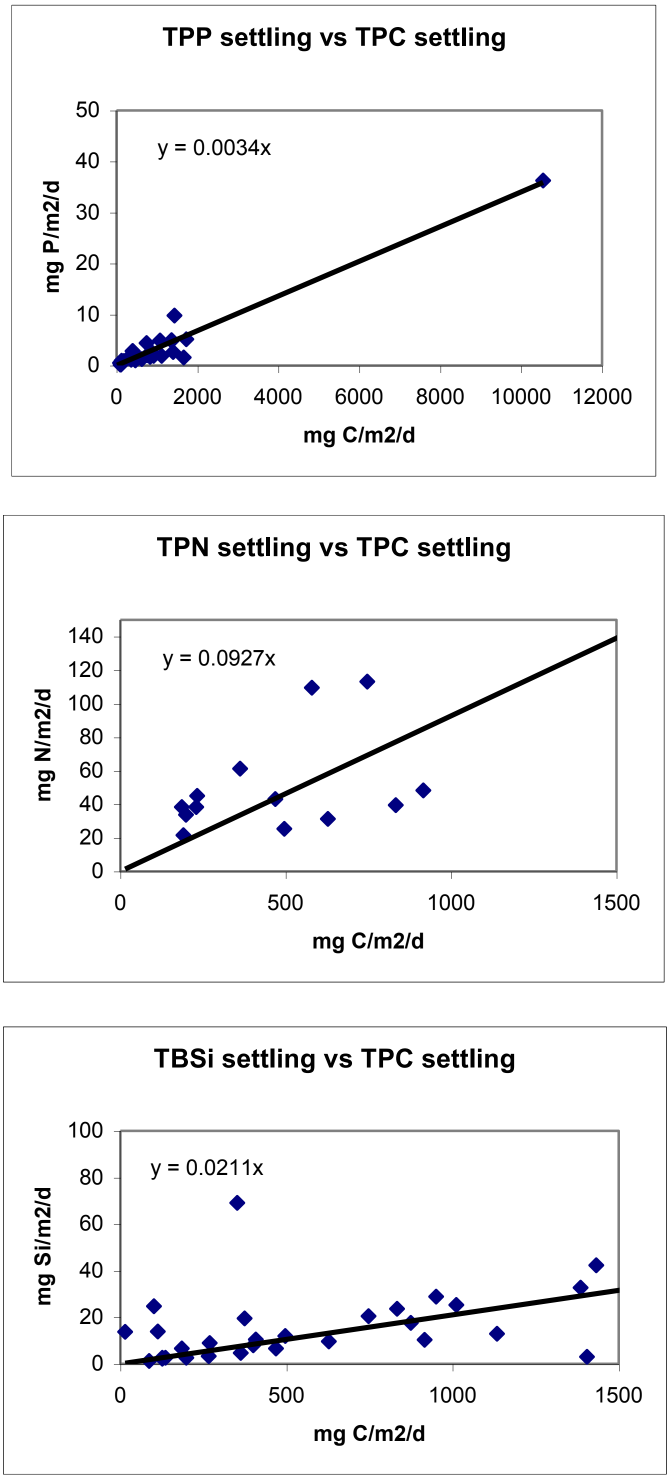

Figure 1.6 Sedimentation of TPP, TPN and TBSi vs sedimentation of TPC

1.4.4 Settling velocity

The slope of regressions between sedimentation rates (mg/m2/d) and the particle concentration at the exposure depth (mg/m3) reveal the settling velocity (m/d) shown in Figure 1.7:

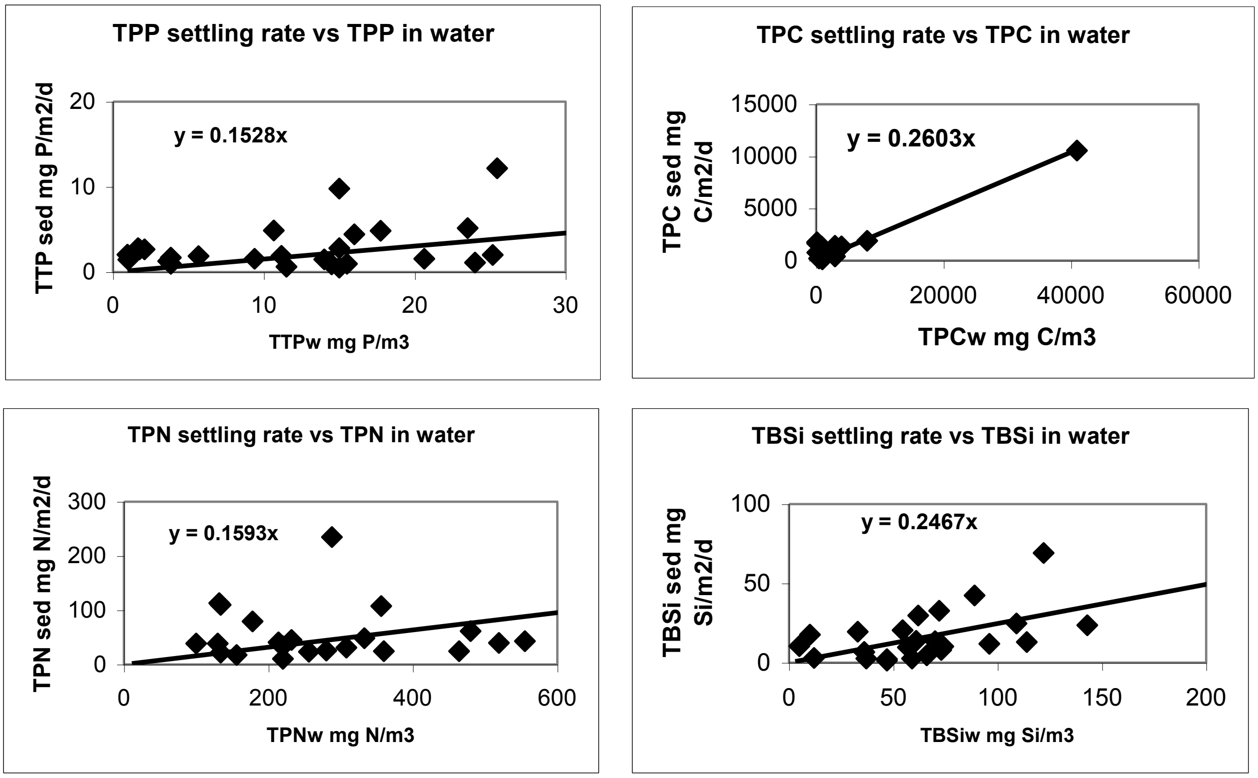

Figure 1.7 The sedimentation rates of TPP, TPN, TPC and TBSi vs concentrations in water

The settling velocities for TPC and TBSi - 0.25-0.26 m/d - are higher than the velocities for TPP and TPN - 0.15-0.16 m/d. This reflects that detritus particles and diatoms with relatively low contents of N and P settle faster than other phytoplankton groups. In general the measured settling velocities are lower than those used in the Lake Victoria Model (0.2 -0.6 m/d).

1.4.5 Flux experiments and pore water profiles

These activities have not been implemented in the field nor in the laboratory programmes because of the lack of core sampling equipment. Only recently has the equipment been purchased by the Entebbe laboratory and it is not yet available at the laboratories in Kisumu and Mwanza .

1.5 Summary and conclusions

A set of lake wide data on sedimentation rate and settling velocities of TPP, TPN, TPC and TBSi has been sampled and analysed in the period November 2000 to September 2001. The loss of exposed traps especially at near shore stations (>50%) and lack of analytical equipment especially for TPC in Mwanza and for TPP and TPN in Mwanza and Entebbe placed limitations on the completeness of the sedimentation study.

The results show that sedimentation rates are highest at the littoral stations compared to pelagic stations, but the differences are smaller than the variations in chlorophyll concentrations and secchi depths. The stochiometric composition of the settling material indicates nitrogen limitation and a non-dominance of diatoms. The differences in settling velocities indicate that the settling material consists dead and living material with a contribution of diatoms.

1.6 Recommendations

The collection of pelagic sedimentation data (sediment traps) should continue, but at reduced frequency, eg. only on quarterly cruises.

To increase the retrieval success at near-shore stations arrangements for surveillance should be made with local fishermen rather than experimenting with attractiveness of the surface buoys

Coring equipment should be purchased and flux experiments and pore water profiling should be initiated with priority given to pore water profiles

The importance of river plumes should be assessed by transects of cores at locations identified from aerial photos. The cores should be undisturbed and should be analysed for granulometric composition and content of available nutrients