# Water quality and nutrient dynamics – Lake Victoria, Kenya

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**Abstract:** Limnological studies in Lake Victoria (Kenyan portion) have been sporadic. Water quality and nutrient dynamics studies are being undertaken in fifteen sampling sites that have been divided into four ecological zones namely; Nyanza Gulf, Rusinga Channel, open waters inshore and open waters. The ongoing study will show how the physical and chemical parameters affect fish distribution and abundance.

## Introduction

Lake Victoria, the largest lake in Africa (68 000 $km^2$), is the most important freshwater resource for the people living in its catchment. Fishing and associated post-harvest activities are amongst the most important economic activities of the region. Also a rapidly growing population of more than 31 million in its catchment depends on the lake for supply of protein.

In the last 30 years, the waters of Lake Victoria have been progressively enriched with nitrogen and phosphorus (Ochumba & Kibaara 1989). This has led to the accumulation of organic matter in the water and changes in its chemical properties often resulting in the degradation of the water with respect to its suitability for consumptive, industrial and agricultural uses.

Ecological studies in the Lake Victoria, especially those related to physical and chemical characteristics of the water have received little attention. Studies have focussed on alien fish introductions (e.g. Ogutu-Ohwayo 1990), macrophytes (e.g. Gichuki & Odhiambo 1994), changes in fish compositions (e.g. Okemwa 1984) and algal blooms (e.g. Ochumba & Kibaara 1989). This is considered a narrow focus, and to understand the dynamics of the fisheries, an important food resource for the peoples of the region, there is a fundamental requirement to determine how physical and chemical parameters affect the distribution and abundance of the fish stocks. This paper presents preliminary findings of limnological studies in the Kenyan sector of Lake Victoria, as a precursor to more in depth analysis of the way physical and chemical parameters affect the fish stock dynamics.

## Materials and methods

The Kenyan part of Lake Victoria is at 1134 m above sea level and is located between 0°04'S - 0° 32'S 34° and 13'E - 34°52'E. Sampling sites were selected to be representative of the Kenyan waters of the lake and indicative of the experimental trawling stations.

Fifteen sampling sites were selected in four ecological zones (Fig. 1). The Nyanza Gulf zone was represented by eight sites: Kisumu Pier [10]; Sondu Miriu [2]; Awach River Mouth [3]; Homa Bay Pier [9]; Asembo Bay [26]; Gingra Rock [4]; Maboko;

and Madundu. The Rusinga Channel [34] was the second zone. The third zone was in the open waters outside the Nyanza Gulf, and was sampled at Bridge Island [32]. The fourth zone comprises the Yala River mouth [54], Sio River mouth and Nzoia River mouth[53], in the north of the lake, and the Kuja River mouth and Muhuru Bay, in the south.

Samples were collected, where possible, on a monthly basis between October 1997 and July 1999 to obtain information on the main physical and chemical characteristics and assess how they affect natural production.

*In situ* measurements for temperature and dissolved oxygen were made using a YSI model 57 oxygen meter, pH was measured using a digital mini model 49, and conductivity measured using a microprocessor conductivity meter LF 96. In addition, redox potential was measured automatically using a Hydrolab Surveyor II connected to an SVR 2 –DU display and 401 -CA circulator assembly. Turbidity was measured using a Hatch turbidimeter 2100P. Light penetration was taken as extinction of a 20-cm black and white secchi disc. Total alkalinity and total hardness were determined by titrating 100 ml of each sample against a standard solution of a strong mineral acid and ammonium hydroxide respectively.

At each station, and on each occasion, water samples were collected in polyethylene bottles for nutrient analysis. They were preserved with 1 mL mercuric chloride and stored at 4°C in the laboratory. The samples were filtered through a cellulose acetate membrane with nominal pore size of 0.45 μm. The filtrate was saved for analysis of dissolved chemical species as recommended by Gems (1992) and Mackereth *et al.* (1978).

**Results**

Marked differences in the mean dissolved oxygen concentration [$0_2$] (mg $L^{-1}$) and temperature (°C) profiles were found between sampling stations and sampling zones (Fig. 2). Two sampling stations had levels of [$0_2$] below 3 mg $L^{-1}$, which is considered the critical level for survival of the major commercial fish species. (The optimum [$0_2$] for fish survival is 5 mg $L^{-1}$, critical [$0_2$] is 3 mg $L^{-1}$ and levels below 3 mg $L^{-1}$ are considered lethal). These two sampling stations in the Nyanza Gulf zone were Awach River mouth and Homa-Bay pier, both of which are characterised by extensive coverage of water hyacinth, *Eichhornia crassipes* (Mart.) Solms, and shallow depths.

Kisumu pier and Maboko stations in the Gulf zone had mean [$0_2$] of >5 mg $L^{-1}$ at the surface but critical (3 mg $L^{-1}$) at the bottom. The remainder of the sampling stations in the Gulf (Sondu Miriu, Gingra Rock and Madundu) had mean dissolved oxygen concentrations of 5 mg $L^{-1}$ or more.

Stations in the inshore region of the open lake that exhibited a decrease in [$0_2$] to critical levels as depth increased were Muhuru Bay, Yala River mouth and Nzoia river mouth. Muhuru Bay is a deep sampling station (16 m deep) and exhibited thermal stratification, hence the decrease in the level of oxygen in deeper water. However, Yala River mouth and Nzoia River mouth are no deeper than 5 m, and the low [$0_2$] is probably linked to the influence of the river discharges which carry considerable organic effluent and have high suspended solids loadings.

Bridge Island, another open water zone, is a deepwater station (41.2 m), which exhibits the effect of thermal stratification, with a sharp drop in $[0_2]$ from 5 mg $L^{-1}$ to <3 mg $L^{-1}$ around the thermocline at about 30 m. Although Rusinga Channel is a deep water station (52 m), there was no evidence of thermal stratification or a degradation of the $[0_2]$ with increasing depth. This is probably because the water currents between the inner gulf region and the open water of the lake continually mix the waters.

Mean chlorophyll-a (mg $L^{-1}$) concentrations showed contrasting results between the Nyanza Gulf sampling sites and those in the open waters (Table 1). Considerably higher values were found within the gulf, especially around urban centres, possibly reflecting nutrient input and cultural eutrophication.

Mean nitrate (mg $L^{-1}$) concentrations in the different zones (Table 1) showed similar trends to those of chlorophyll-a, with the highest levels (0.33 mg $L^{-1}$) in the Gulf waters below the Sondu Miriu mouth, and the lowest concentrations (0.02 mg $L^{-1}$) in the open waters around the Nzoia River mouth.

Mean phosphates (μg $L^{-1}$) concentrations (Table 1) showed no obvious trend, although higher levels were again found around urban centres and around the discharge points of the major rivers, the latter possibly indicative of fertilizer run-off.

Silicate concentrations (mg $L^{-1}$) were much higher in the gulf than in the open waters Table 1).

The eutrophic effects, were further supported by the mean secchi disc depths, which were low in the gulf waters but generally higher in the open waters, the exceptions being where major rivers discharge into the lake (Table 1).

## Discussion

The limnological surveys of the Kenyan waters exhibit a number of features that are indicative of the water movements, thermal stratification, pollution, eutrophication and primary production processes.

Thermal stratification only occurs in the deeper waters and was most prevalent around Bridge Island, and to a lesser extent at Yala river mouth and Muhuru Bay. Rusinga Channel, which is also a deepwater site, did not exhibit stratification, presumably because of the continuous mixing of waters between the open lake and the Nyanza Gulf.

Depleted oxygen concentrations were prevalent throughout the lake but fell to critical levels for survival of fish around Homa Bay and Awach River mouth. These sites were characterised by extensive coverage of water hyacinth, which is known to deplete oxygen below the vegetation.

The mean concentration of chlorophyll a in the water, an indicator of primary productive, also varied between regions. Chlorophyll a levels were highest in the Gulf zone and declined towards open waters. It is important to note that this trend is not reflected in the nutrient ($PO_4$ and $NO_3$) levels, suggesting that the latter are not limiting factors to primary production. This is probably more a reflection of nutrient enrichment which is continually taking place around the inshore waters from urban and agricultural sources. This is particularly noticeable around the mouths of the major rivers which drain agricultural land, e.g. the Sondu Miriu, and large urban centres like Homa Bay and Kisumu.

The high chlorophyll concentrations in the Gulf area are a result of higher densities of diatoms and dinoflagellates, factors which suggest that eutrophication is prevalent in the Gulf region. The Gulf also has higher silicate concentrations than open waters. Silicates are important for diatom cell wall development.

These variations in dissolved oxygen concentrations, nutrient availability and phytoplankton abundance all have implications for the fisheries production of the lake. The loss of the many phytoplankivorous haplochromines following the introduction of Nile perch, *Lates niloticus* (L.), has left a food niche in the lake which has been occupied by *Rastrineobola argentea* (Pellegrin) and the resurgence of *Yssichromis fusiformis* (Greenwood and Gee) and *Y. laparogramma* (Greenwood and Gee), two haplochromines which appear to be able to tolerate the predation pressure of Nile perch. There is thus a need to continue to monitor the limnological characteristics of the lake both in Kenyan waters and the other countries, to fully understand the trophic dynamics of the system. Ultimately this information will be fed into the ECOPATH model to elucidate factors affecting the status of the fish stocks in the lake.

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**Table 1.** Mean nutrient concentrations and secchi depths for limnological sampling sites in Kenyan waters of Lake Victoria.

| Station | Position (by GPS) | Silicates (mg L$^{-1}$) | Nitrates (mg L$^{-1}$) | Phosphates (µg L$^{-1}$) | Chlorophyll (µg L$^{-1}$) | Secchi depth (m) |
|---|---|---|---|---|---|---|
| Nyanza Gulf | | | | | | |
| Kisumu Pier [10] | 00°06'09"S 34°44'32"E | 4.10 | 0.05 | 41.17 | 38.07 | 0.55 |
| Sondu Miriu [2] | 00°17'00"S 34°44'42"E | 7.14 | 0.33 | 44.75 | 12.35 | 0.50 |
| Awach river mouth [3] | 00°20'17"S 34°38'45"E | 6.30 | 0.13 | 77.25 | 10.68 | 0.70 |
| Homa Bay Pier [9] | 00°30'53"S 34°27'41"E | 4.87 | 0.03 | 77.25 | 20.04 | 0.75 |
| Asembo Bay [26] | 00°12'35"S 34°24'33"E | 5.20 | 0.03 | 22.84 | 37.45 | 0.75 |
| Gingra Rock [4] | 00°20'37"S 34°26'30"E | 3.23 | 0.11 | 52.63 | 16.44 | 1.03 |
| Madundu | 00°25'32"S 34°19'59"E | 5.03 | 0.15 | 36.00 | 15.60 | 0.90 |
| Rusinga Channel | | | | | | |
| Rusinga Channel [34] | 00°20'57"S 34°13'54"E | 2.17 | 0.11 | 74.92 | 16.31 | 1.6 |
| Open Lake | | | | | | |
| Bridge Island [32] | 00°20'34"S 34°06'30"E | 1.03 | 0.11 | 89.71 | 6.30 | 2.60 |
| Open lake - inshore | | | | | | |
| Yala river mouth [54] | 00°03'36"S 34°02'19"E | 0.67 | 0.02 | 32.21 | 9.77 | 1.34 |
| Sio river mouth | 00°13'47"N 34°00'15"E | 1.89 | 0.03 | 22.42 | 10.80 | 1.03 |
| Kuja river mouth | 00°55'20"S 34°07'41"E | 1.73 | 0.08 | 74.71 | 14.13 | 0.98 |
| Muhuru Bay | 00°57'49"S 34°06'08"E | 3.59 | 0.18 | 75.13 | 8.13 | 1.90 |
| Nzoia river mouth [53] | 00°03'46"N 33°56'40"E | 1.53 | 0.02 | 41.35 | 7.86 | 0.75 |

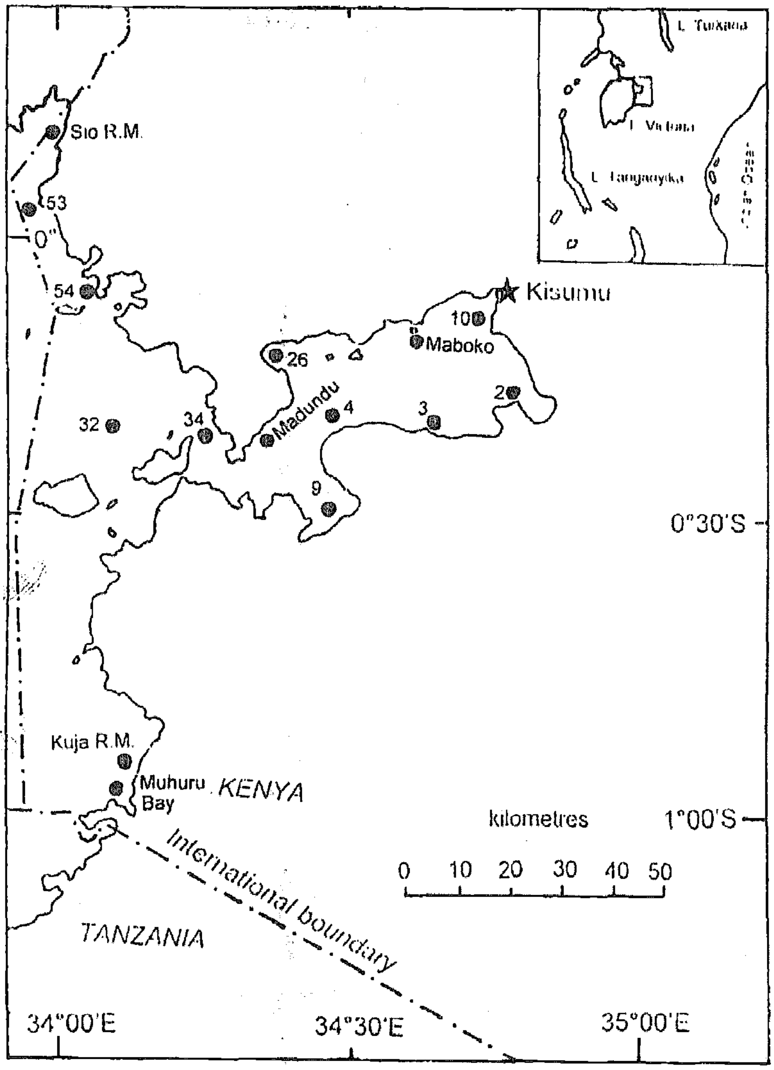


Fig. 1. The Kenyan waters of Lake Victoria, showing the sampling sites (●) listed in the text and in Table 1.

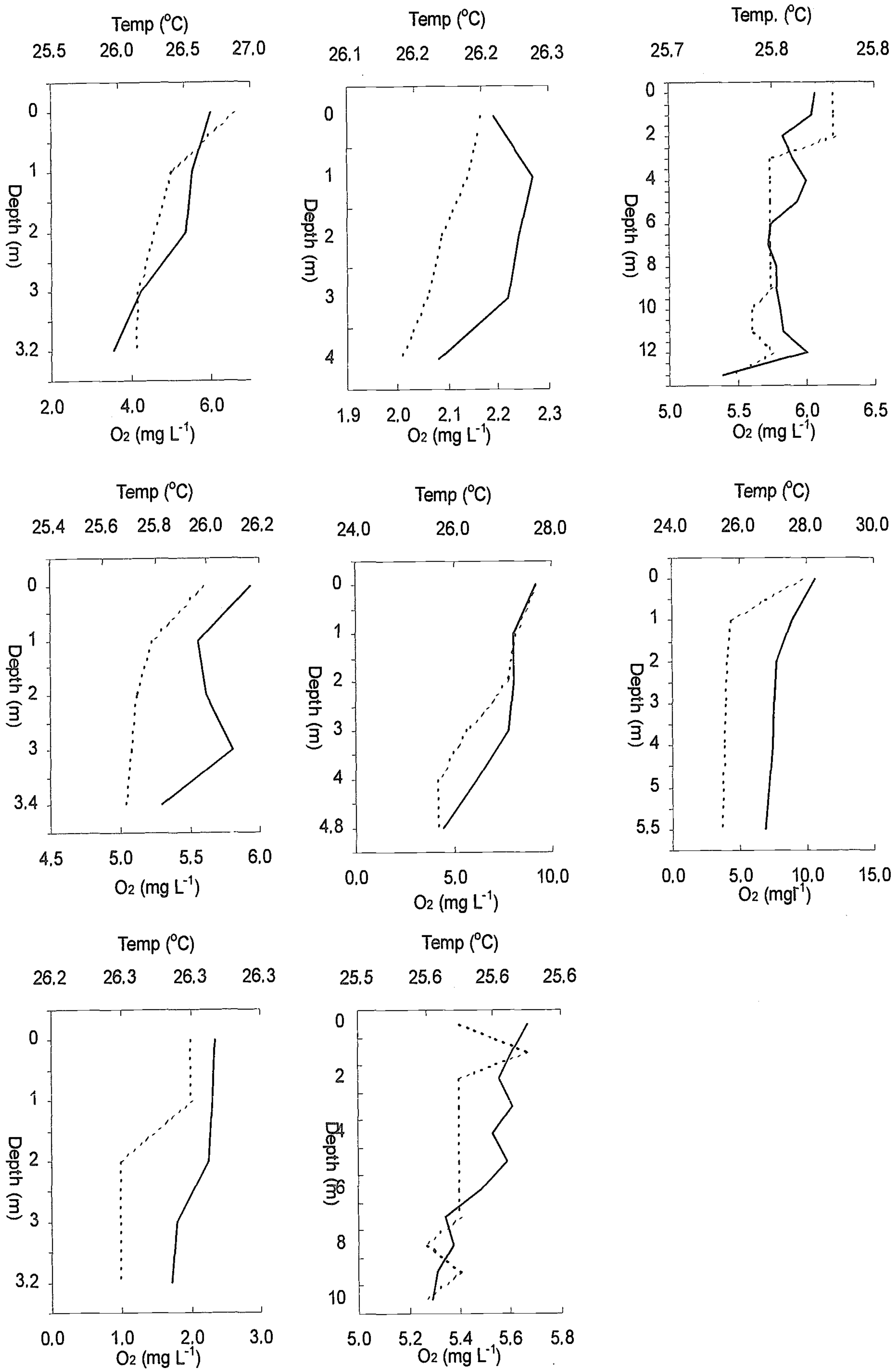


**Fig. 2.** Depth profiles for mean oxygen (dashed line, mg $L^{-1}$ and temperature (solid line,° C) from October 1997 - July 1999.

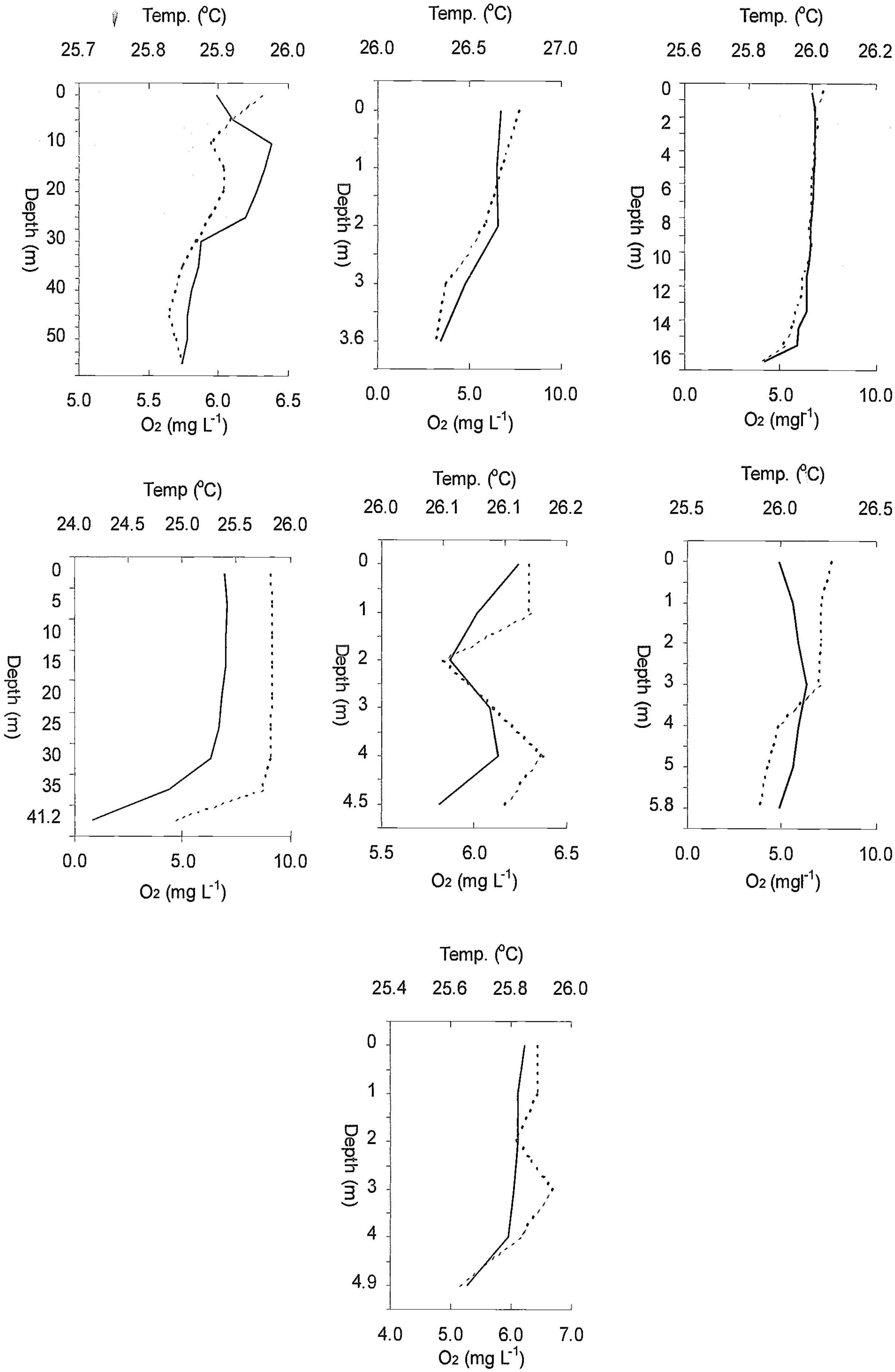


**Fig. 2 cont** Depth profiles for mean oxygen (dashed line, mg L-1) and temperature (solid line, 0C) from October 1997-July 1999