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Recent climate and limnology changes in Lake Tanganyika

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Introduction

The possible effect of recent climate change on Lake Tanganyika limnology has not previously been investigated, although the abundance of pelagic fishes is changing (Plisnier in press). Recent data collected in the framework of the Lake Tanganyika Research project (LTR) of FAO/FINNIDA allow some preliminary analyses on recent climate–limnology changes.

Material and methods

The Bujumbura meteorological station lies at the northern end of the lake (3.32° S, 29.32° E), while the Mbala station is situated 40 km from the southern end (8.85° S, 31.33° E). Both stations are part of the World Meteorological Organisation network. The lake temperature was measured with a CTD-12+ instrument (accuracy ±0.01 °C) and an automatic ANDERAA thermistor string installed in the south of the lake (accuracy ±0.1 °C). DO was measured with a Yellow Springs Instrument equipped with a submersible stirrer. Accuracy was ±0.01 mg/L DO. Transparency was measured with a standard secchi disk.

Results

Since the 1960s, an increase in air temperature has been noted at two stations, one in the north and one south of Lake Tanganyika. The mean increase, based on the linear regression of monthly data between 1964 and 1990, was 0.7 °C at Bujumbura Airport and 0.9 °C at Mbala Airport (Fig. 1).

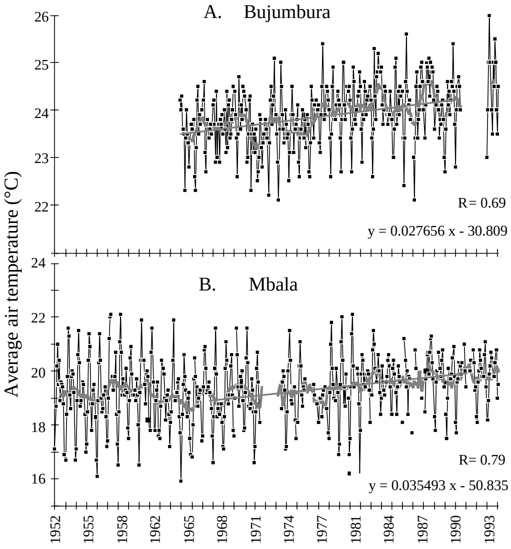

Fig. 1. Changes in monthly average air temperature at (A) Bujumbura from 1963 to 1993, and (B) Mbala from 1952 to 1993. Regressions are calculated for the period 1964–1990 (from data from the Institut Géographique du Burundi and the Departement of Meteorology, Zambia, personal communication).

The position and geographical orientation of Lake Tanganyika make it particularly dependent upon regular unidirectional SE trade winds from May to September. This has an important effect on the tilting of the epilimnion. Water movements (progressive wave and reactivation of internal waves) follow the shift in direction of the monsoons. Wind speed has decreased in recent years in the Lake Tanganyika area (Fig. 2). The monthly mean speeds at Bujumbura fluctuated between 1.4 and 2.5 m/s on average from 1964 to 1979. Between 1986 and 1990, the range was from 0.5 to 1.5 m/s. At Mbala, the mean wind also decreased from the end of the 1970s to a minimum in 1983. The speeds then increased but not to the previous levels. However, data were incomplete. Although subjective, it is interesting to note that local fishermen at the south of the lake have reported wind strength diminishing from

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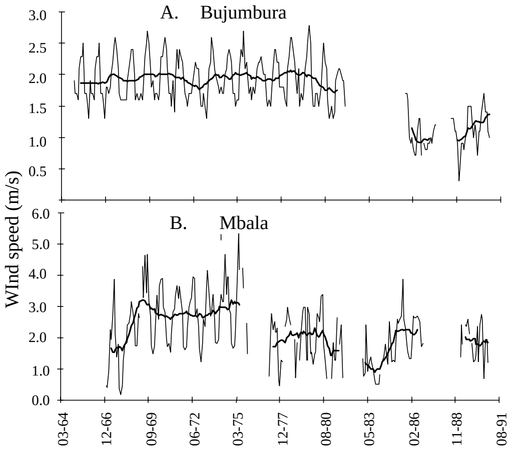

Fig. 2. Wind speed (m/s) at Bujumbura and Mbala: monthly data and running yearly means (after data from the Institut Géographique du Burundi and the Departement of Meteorology, Zambia, personal communication).

the late 1970s (personal communication).

The temperature profiles in the upper part of Lake Tanganyika (0–100 m) near Bujumbura were significantly ($P < 0.01$) warmer in 1993–1994 than in 1956–1957 (Dubois 1958). The mean surface temperature near Bujumbura was 25.99 °C in 1956–1957 compared to 26.33 °C in 1993–1994. The difference in temperature between the above time periods was greater during the dry season, 0.40 °C, than during the wet season, 0.28 °C. In the south of the lake, Coulter (1968) recorded a range in surface temperatures from 23.3 °C to 24.0 °C and mentioned that the water column was frequently homothermal at ca. 23.5 °C. During the dry season of 1993–1994, LTR has recorded all surface temperatures >23.90 °C in the south.

There are also indications of deeper warming (Table 1). However, the number of observations published from the early period is not sufficient for statistical tests and their accuracy is questionable. We may only observe that reported measurements for water temperature of Lake Tanganyika are all showing an increase with time.

The mean thermocline depth in the north of the lake was 68 m in 1955–1957 (Dubois 1958) and 55 m in 1993–1994 (Fig. 3A). The difference is particularly important when comparing the main dry seasons (June to September) (Fig. 4A). The thermocline depth was similar in 1994–1995 and 1995–1996 compared to 1993–1994. In the recent period, the nutrient rich layers are closer to the euphotic zone.

Water in the pelagic zone in the north of the lake was not as clear (9 m) in 1993–1994 as in 1955–1957 (13.6 m) (Dubois 1958) (Fig. 3B). The transparency was different mainly during the dry season of each period (Fig. 4B). In 1955–1957, the transparency showed a significant increase with thermocline depth. In the south, the water was clearer in the recent period; mean secchi depths were 12.1 m in 1993 and 9.6 m in 1994 compared to 8.0 m in 1961 (Coulter 1991). It is not known if this reflects a general trend or was due to interannual variability.

The oxygenated layer was shallower in 1993–1994 compared to 1946–1947 and 1955–1957 particularly during the dry season (the oxycline depth was ca. 60 m in 1993–1994 and 80–100 m in 1946–1947). Anoxic conditions (<1 mg/L DO) in the north were mea-

Table 1. Mean temperature (100–300 m) for 1946–47 (Van Meel 1987), 1973 (Craig et al. 1974) and 1993–1994 (LTR).

Depth (m)	1946–1947 (Van Meel 1987)	1973 (Craig et al. 1974)	1993–1994 LTR
100	23.88	24.02	24.18
150	23.52	23.71	23.85
200	23.42	23.55	23.67
250	23.40	23.44	23.54
300	23.32	23.38	23.46

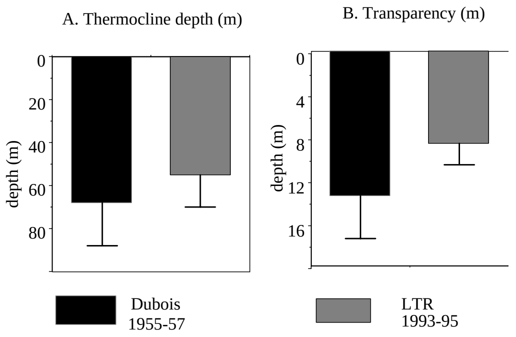

Fig. 3. Yearly mean (±standard deviation) (A) thermocline and (B) secchi depth (m) near the northern end of the lake in 1955–1957 (Dubois 1958) and 1993–1994.

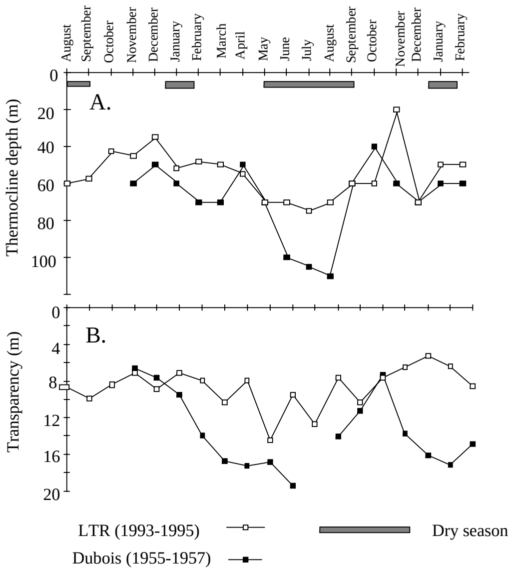

Fig. 4. Monthly data of (A) thermocline depth (m) and (B) transparency (m) near the northern end of the lake in 1955–1957 (Dubois 1958) and in 1993–1994.

sured at 100 m during the dry season in 1993–94 compared to 130 m in 1946–47. A lower tilting of the epilimnion during the dry and windy season and increased stratification could explain the shallow oxygenated layer in the north. The seasonal differences in surface oxygenation were well marked in 1946–47 and 1955–57 but much less so in 1993–94.

In 1993–1994, a higher zooplankton density was measured in the north of the lake than in the south (Kurki, personal communication). However, shrimps and adult *Lates stappersii* are actually more abundant in the south. *Lates stappersii* feed heavily on shrimps there (Mannini, personal communication) rather than on *S. tanganicae*, which has been rare in the catches for several years.

Discussion

Although the warming (0.34 °C for the upper 100 m) of Lake Tanganyika should be confirmed through several years of sampling, it may be noted that it is similar to the warming noted in Lake Victoria – 0.3 °C compared to the first part of the century (Hecky et al. 1994). The productivity of African Great Lakes is determined to a large extent by the strength of stratification and the amount of the hypolimnion water brought to the surface. A warming of Lake Tanganyika would probably enhance the thermic stratification since density differences increase non linearly with temperature.

In the past, cooler conditions may have caused not only important quantities of nutrient-rich waters but also larger quantities of deep anoxic water containing hydrogen sulphide or ammonia to rise up to the surface. Fishermen in the south of the lake reported that fish kills were more frequent in the 1960s and 1970s than during the last 15 years.

The changes in thermocline depth, transparency and depth of the oxygenated layer are coherent with a change in the strength of wind force leading to a decreased tilting of the epilimnion. This could have led to an altered hydrodynamic state of the lake in recent years.

Conclusions

Any change in the current hydrographic regime, which would permit greater mixing across the thermocline, could substantially alter the productivity of the lake. Eutrophication in the north is unlikely to be caused by higher external nutrient loading. There is no evidence of more frequent use of fertilisers in the region. Furthermore, runoff water rapidly descends below the thermocline because it is often colder. Climate change (warming and decreased winds) may have caused the thermocline to be closer to the surface there. This could be an important cause for increased primary productivity in the north of the lake since the nutrient rich hypolimnion is there at the limit of the photic zone (40–50 m). Decreased depth of the oxic layer may, however, be a limiting factor for pelagic fishes.

Acknowledgements

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