

Ecology

# Climate change effect on Lake Tanganyika?

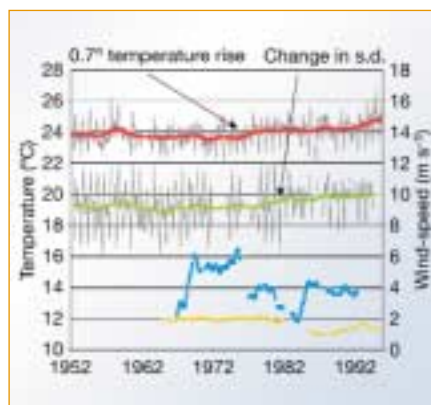
Arising from: C. M. O'Reilly, S. R. Alin, P.-D. Plisnier, A. S. Cohen & B. A. McKee *Nature* **424**, 766–768 (2003).

In their analysis of Lake Tanganyika's ecosystem<sup>1</sup>, O'Reilly *et al.* say that climate change, in the form of rising temperatures and falling winds, is causing a decline in the lake's productivity. However, their own data establish that air temperatures were either steady or dropped slightly between 1952 and 1978, rising only slightly between 1980 and 1992, and that wind-speeds have increased by 35% since 1985. These climate changes therefore have no correlation with either lake temperature or productivity, so it cannot be inferred from their data that climate change is the cause of the productivity decline.

The authors claim that trend lines indicate that air temperatures at the lake warmed about 0.5–0.7 °C. However, trend lines do not reveal changes over time — gaussian averaging gives a better insight. The authors' data<sup>1</sup> for Mbala and Bujumbura (Fig. 1) reveal that there was no change or a slight decrease in average temperature between 1952 and 1975; Bujumbura wind-speed was unchanged between 1967 and 1975, and Mbala wind-speed increased over that period.

If climate change were the reason for the decline in productivity, we should see no such decline between 1952 and 1975, or might even see an increase due to rising Mbala wind-speeds. Nor should we see any change in water temperature, as there was no air-temperature change. However, despite steady temperatures and rising winds, the authors' figures for productivity<sup>1</sup> (their Fig. 3) show a steady decline during that time, and their figure for water temperature (their Fig. 2a) shows an increase of roughly 0.25 °C (ref. 1).

After about 1975, both the temperature and wind records become suspect, with a considerable amount of missing data. There is an abrupt 0.7 °C rise in the temperature in Mbala in 1980, accompanied by a large



**Figure 1** Historical monthly weather records for Lake Tanganyika. Temperature data: red line, Bujumbura; green line, Mbala (gaussian average over six years); grey lines, monthly temperatures. Wind-speed data: blue squares, Mbala; yellow dots, Bujumbura (gaussian average over two years). Created with original O'Reilly *et al.* weather data.

reduction in standard deviation (see O'Reilly and colleagues' Fig. 1a: standard deviation 1952–80, 1.22; s.d. 1980–94, 0.95). This looks as though there has been either an artificial splicing of two records or a change in thermometer location, particularly as the same pattern is not present in Bujumbura.

The later parts of both wind records are particularly poor. After a year's gap in 1976, the Mbala wind records resume sporadically (a full quarter of the post-1976 Mbala monthly data is missing), with much lower values and standard deviation (s.d. 1967–75, 2.0; s.d. 1976–92, 1.4).

Between 1967 and 1982, the Bujumbura wind data are complete; there is not a single missing month. But after a three-year hiatus (1982–85), 17% of the Bujumbura monthly data is missing, and radically lower values are reported. I suggest that the wind figures after the gaps should be used with caution unless they can be confirmed by other observations.

*O'Reilly et al. reply* — Eschenbach<sup>1</sup> questions the validity of our climate record and our proposed link between climate and lake ecosystem change. Here, we address the three main themes: our meteorological data; the timing of limnological changes; and the warming of Lake Tanganyika.

Our meteorological data are sufficient to indicate likely trends in local climate for three reasons.

First, there has been no change in either the location of the station or the instrumentation in Bujumbura and an independent analysis of the data shows a 0.6 °C warming over the last 80 years (M. Shiramanga, per-

sonal communication). The Mbala meteorological station has not changed location and underwent a change in instrumentation for temperature (but not for wind-speed) in 1984 (I. Jere, personal communication). The heat-island effect is an unlikely cause of warming because there has been no urban development at either location.

Second, the pattern of reduced variability seen in the latter part of the air-temperature record is consistent with reduced diurnal temperature ranges (as much as 0.5–1 °C since the 1950s; ref. 2) observed elsewhere in eastern Africa and around the world<sup>2–4</sup>. A change in standard deviation of the climate

For the sake of argument, let us assume that the wind records of O'Reilly *et al.* are correct. From their data<sup>1</sup>, we can draw several conclusions. First, air temperatures were steady or dropped slightly at Lake Tanganyika between 1950 and about 1978. They rose abruptly, and then rose only slightly during 1980–90, after which only temperatures at Bujumbura rose. However, we see no sign of this pattern in either water temperature or lake productivity (Figs 2, 3 of ref. 1). In particular, water temperatures rose between 1950 and 1978, whereas air temperatures were unchanged or dropped slightly; water temperatures fell over 1993–96 (and continued to fall through 2003), whereas air temperatures rose slightly from 1993 to the end of the record in 1996. Also, all their productivity indices dropped between 1952 and 1965, when air temperatures were dropping slightly rather than rising.

Second, the wind-speed data of O'Reilly *et al.* have several problems, but purport to show a rise in Mbala wind-speed between 1967 and 1975, a sudden drop in 1976 and a dip in 1978–84, followed by a 35% increase lasting to 1996. The authors say that wind in Mbala is critical for productivity, but their productivity data do not reflect these wind changes. The productivity data series that extends past 1970 shows an overall productivity decrease from 1970 to 1996 (one series shows a short-lived rise in about 1990).

Third, as both the wind and air-temperature data are so poor, and as there is no correlation between the reported temperature changes and wind changes on the one hand and the productivity and water-temperature data on the other, the null hypothesis (that changes in productivity are not the result of climate change) cannot be rejected. Based on the authors' data, therefore, the productivity changes cannot be ascribed to climate change.

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record does not constitute proof that the jump in temperature and/or wind-speed is not real. Gizozo and Mparambo weather stations in Burundi indicate a comparable rise in temperature of 0.2 °C each decade, including a sharp increase in air temperature between 1977 and 1979 (ref. 5).

Third, although these local climate data lack the continuity and resolution (that is, sub-monthly) required for extensive statistical analysis, the magnitude and patterns are consistent with longer and higher-resolution regional records<sup>2,3,6–10</sup>.

Limnological changes would not be expected to coincide directly in time with cli-

mate shifts/transitions. This is because the climate, limnological and core data derive from different locations of this large ecosystem. Furthermore, both limnological records and core data have low resolution relative to the monthly climate data, making it difficult to determine the exact timing of changes in the lake. And finally, there are time lags associated with the lake's response to warming, which may be magnified as one travels up the foodweb.

Lake Tanganyika has warmed. In our view, there is no plausible mechanism other than climate change to explain this warming adequately. Even if there had been no change in wind-speed, 97% more energy would be required to mix the lake on the basis of the

increased temperature stratification. Therefore, unless wind-speeds increased dramatically, a reduction in deep-water nutrient input would still be expected, with a subsequent decrease in primary productivity.

Although the available meteorological time series data are not optimal, the uncontested warming of the lake and a multitude of regional climate observations confirm that climate is the most parsimonious explanation for the recent productivity changes in Lake Tanganyika.

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