FLUCTUATIONS OF RIFT VALLEY LAKES MALAWI AND CHILWA DURING HISTORICAL TIMES: A SYNTHESIS OF GEOLOGICAL, ARCHAEOLOGICAL AND HISTORICAL INFORMATION

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1. Abstract

Synthesis of geological, historical, archaeological and geographical information is used to reconstruct detailed chronologies of the fluctuations of Lakes Malawi and Chilwa during the past two centuries and to produce less detailed, longer-term chronologies of these lakes. Fluctuations are compared with famine and drought records during historical times and rainfall data during modern times in order to understand their links with local and large-scale climatic conditions. This analysis underscores complexities in interpreting the historical and geological records of the lakes in terms of climate. It also points out the need to interpret the African lake record collectively, rather than focusing on individual lakes.

2. Introduction

The climatic history of equatorial Africa is strongly reflected in the fluctuations of the region's great lakes. The geological record of Lakes Chad, Victoria, Nakuru and others in East Africa (Butzer et al. 1972) unequivocally demonstrated the late Pleistocene aridity in the region and the humid period of the early Holocene, dramatically refuting the prevailing notion of the correspondence between tropical "pluvials" and higher latitude "glacials". Historical witness of the lakes has provided a wealth of information on fluctuations on time scales of centuries (Nicholson 1981, 1995). This, together with early quantitative records of the lakes, demonstrated two major shifts of the prevailing climatic regime in the tropics towards the end of the 19th century and during the 1960s (Kraus 1955; Lamb 1966).

In this paper, the fluctuations of the southern Rift Valley Lakes Malawi and Chilwa are examined. A twelve-hundred year chronology of Lake Malawi is produced that represents a synthesis of published archaeological, geological and historical information and new historical climate chronologies for the region. The record provides good detail of fluctuations during the last six centuries. A shorter chronology is developed for Lake Chilwa. Available evidence demonstrates that within the last one or two millenia,

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fluctuations of at least 14 m and 12 m occurred in Lakes Malawi and Chilwa, respectively.

This work builds upon the records of these lakes that were compiled by Owen et al. (1990), Crossley et al. (1984), Pike (1965), Drayton (1979), Lamb (1966), Sieger (1887) and others. This is one in a series of papers that enhances the record of African lakes over the past few centuries, compares historical evidence with high resolution lake core studies, and compares climatic fluctuations in equatorial and subtropical regions of the continent and in the two hemispheres.

This article includes a summary of general trends over the last two millenia. It also includes detailed chronologies of both lakes from around the 18th century, based primarily on historical references, and compares them with famine and drought chronologies from areas of Malawi, Zambia, Zimbabwe and Mozambique in relatively close proximity to the lake basins. At the outset it was assumed that the reports of famine and drought could enhance the lake chronology developed from references directly pertinent to the conditions of the lakes and rivers. A comparison with the record for Lake Malawi demonstrated that this was not true. Instead, comparison of modern levels with regional rainfall demonstrates that Malawi responds mainly to rainfall in the northern catchment and thus is a better indicator of rainfall in the equatorial region than in its own subtropical latitudes. Also, the highlands may be subjected to more localized rainfall conditions than would be reflected in the lake levels. Lake Chilwa also reflects local rainfall conditions, at least on short time-scales.

2. Geographic Framework

Lake Malawi (Fig. 1) stretches from approximately 9^{O} S to 14^{O} S in the southern Rift Valley. It lies within the countries of Malawi, Tanzania and Mozambique. It occupies a relatively steep basin and has a surface area of 22,490 km^2. Its mean depth and maximum depth are 273 m and 706 m respectively. Its water balance is dominated by rainfall over the lake and evaporation, with river inflow and discharge making only a small contribution (Spigel and Coulter 1996). The fluctuations of Lake Malawi are a reasonably sensitive indicator of regional climate. Mean rainfall over the lake is 1350 mm yr^{-1}, but there is a strong north–south gradient. To the north, Lake Malawi is bordered by highlands where mean annual rainfall exceeds 2400 mm in some places, compared to 1000 to 1200 mm yr^{-1} over most of the rest of the region.

Lake Chilwa, almost directly south of Malawi, occupies a much smaller basin. It is a closed basin lake with a surface area of approximately 1300 km^2 and a depth of about 2 to 3 m. Rainfall in the region is on the order of 1000 to 1200 mm yr^{-1}.

Rainfall is these regions exhibits considerable interannual variability, but the patterns are complex. Lake Malawi straddles the boundary between two large-scale rainfall regions that tend to vary inversely with each other. To the north is eastern equatorial Africa, a region of very diverse mean climates ranging from deserts to rain forests. Despite this diversity, interannual fluctuations are remarkably homogeneous throughout the region spanning latitudes from 5° N to 10° or 12° S (Nicholson 1996).

To the south, in the subtropical latitudes of the southern hemisphere, is another relatively homogeneous area extending to 30° S (Nicholson 1987).

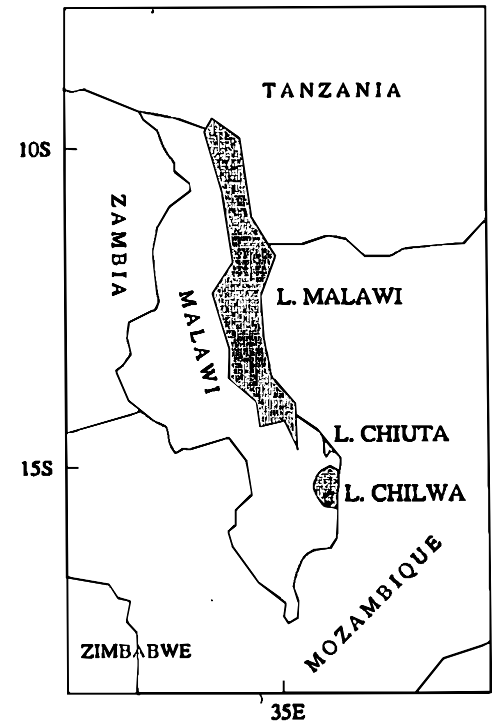

Figure 1. **Map of the area of Lakes Malawi, Chilwa and Chiuta.**

The most common spatial pattern of interannual variability (Fig. 2) is such that when rainfall is above average in one region, it is below average in the other (Nicholson 1986). This is true for both interannual and decadal or longer time scales. The sharp node separating the two regions generally runs just to the north of Lake Malawi in individual years and right through it on decadal time scales, but the lake can lie in either the "equatorial" or the "subtropical" zone. A secondary pattern that prevails is characterized by similar rainfall trends throughout both regions. This complexity of the interannual variability poses difficulties in interpreting fluctuations of the lake in climatic terms. In view of the much higher rainfall to the north, the lake may be more indicative of equatorial rainfall, despite its more southerly location.

Lake Chilwa lies well within the subtropical zone. For this reason, its fluctuations would not necessarily mirror those of Malawi, despite the proximity of the two lakes.

3. Lake Malawi

3.1 GENERAL TRENDS DURING THE LAST TWO MILLENIA

Over historical time scales, the fluctuations of Lake Malawi can be established in a very general sense from archaeological artifacts indicative of lakeshore settlement, from historical witness, and from three pre-modern beach units representing three periods of high stands of the lake within the last two millenia. A summary of the beach units, as dated from artifacts (Crossley and Davison-Hirschmann 1981), is given by Owen et al. (1990) as

1) a level of 476.1 m reached late in the period of Mawudzu pottery tradition (thought to span the mid-12th to mid-18th centuries),

2) a level of 475.6 m reached shortly before or very early in the Mawudzu period, and

3) a level of 476.8 m reached shortly before the period of Nkope pottery tradition, believed to span the 3rd to 10th centuries.

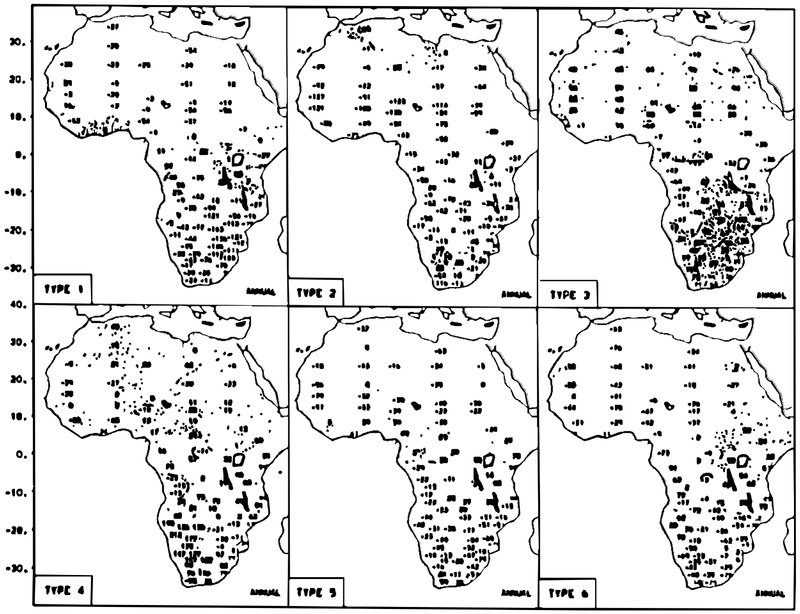

Figure 2. Dominant spatial modes of rainfall variability over Africa, as represented by the most frequently occurring anomaly types (from Nicholson 1986). Positive departures (shaded) indicate above-average rainfall, negative values indicate below-average rainfall. Numbers represent a normalized, regionally-averaged departure from the long-term mean.

Radiocarbon dates on charcoal samples help fix the timing of the first two of these levels (Crossley et al. 1984). A sample from the pre- or early- Mawudzu beach sand was dated as 990 ± 90 B.P., establishing a date of approximately the 10th century for a high stand of the lake. Owen et al. (1990) suggest a date of A.D. 950. Dates on samples post-dating the pre-Nkope beach deposits are 1340 ± 50 B.P. and 1720 ± 90 B.P. These suggest that this high stand would have ended by at least the 2nd century A.D.

The timing of the late Mawudzu high stand is more difficult to establish, in part because it appears to have been a double peaked event (Crossley et al. 1984). The maximum was probably attained sometime before the 15th century A.D., as charcoal within the late Mawudzu beach sand has a radiocarbon date of ca. 480 ± 80 B.P. This same date was obtained from charcoal associated with a stone structure on the Shire River. That structure, probably a wharf or a place for washing and water collecting, implies that at ca. 480 ± 80 B.P. the Shire River stood at a height of about 40 cm above the lake's 1980 level, but several meters below the previous high stand. This river level indicates that the overflow of the lake was not blocked during the late Mawudzu, so that the origin of the high levels was climatic (Crossley et al 1984).

Owen et al. (1990) assign ca. 1390 A.D. to this high stand of Malawi. Its end can be fixed to some extent by tree-growth around the lake. The age of the oldest baobabs, a tree particularly sensitive to rising water and flooding, does not exceed about 225 years. This is consistent with the age of baobabs around Lake Chilwa (see section 4) and indicates that the late Mawudzu high stand of Lake Malawi ended by 1750 A.D. One *Acacia albida* standing on the beach ridge has an estimated age of 360 years, suggesting the phase may have ended as early as 1620 A.D., or that lake levels were falling by then. Floods preventing the establishment of trees prior to these times could have represented a second peak within the late Mawudzu high stand. A more recent high stand, known from historical records, took place ca. 1980 A.D. (Owen et al. 1990; Eccles 1974) following a decade of abnormally high rainfall (Nicholson 1996).

In summary, three high stands of Lake Malawi occurred ca. A.D. 950, A.D. 1390 and A.D. 1980. Lake cores and other materials provide independent evidence for intervening low stands. A core taken near Nkhotakhota shows clear evidence of a recent low stand that historical information (see section 3.2.2) would date as the late 1700s and early 1800s. Plant materials and burrows indicate that the layer at depth 105 to 280 mm in the core was at the time above the level of the lake (Crossley et al. 1984). Three distinct sand layers in the core are probably remnants of three other low stands that occurred prior to the 18th century.

Radiocarbon dates of the archaeological record of shoreline settlements provide further evidence of low stands (Fig. 3). Gaps in the record indicate a settlement shift to follow the receding shore or to migrate to wetter highlands and presumably represent low stands of the lake. Gaps appear from late 15th century to mid-19th (except a single date ca. 1700) and in the 12th and 13th centuries (Owen et al. 1990). These dates are coincident with changes in ceramic traditions and occur mid-way between high stands dated by Crossley et al. (1984) to ca. 1980, 1390 and 950 A.D. The 1700 A.D. date may represent a second peak of the late Mawudzu high stand. Its decline would have been the recession that allowed the establishment of baobabs around the lake. Dating of material in the core by ^{210}Pb suggests that recovery from this dry phase had occurred by ca. 1860 A.D., in accord with historical information described in section 3.2.3.

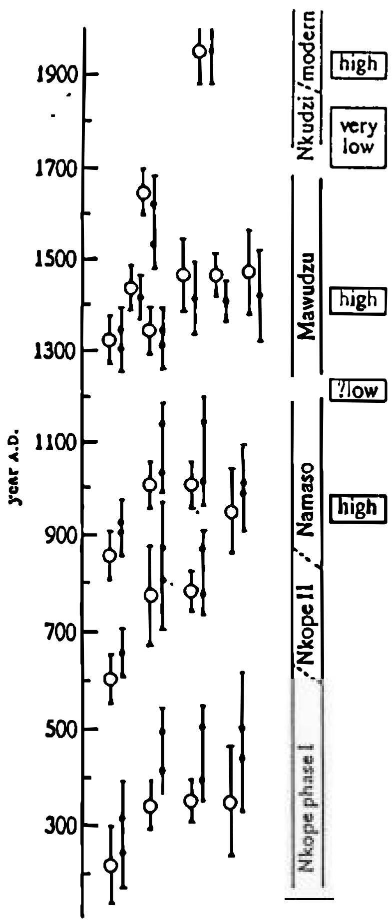

Figure 3. Long-term fluctuations of Lake Malawi, based on radiocarbon-dated archaeological data (from Owen et al. 1990). Large and small circles respectively indicate uncorrected and corrected ^{14}C dates; right axis indicates ceramic traditions. Also indicated on right are periods of high lake level (from Crossley et al. 1984) and inferred periods of low lake level.

Microfossil and lithological evidence of the second gap includes diatoms, dunes and erosional features in the sediment core. Diatoms sharply decline in abundance and diversity and there is a change in dominant species across this break, suggesting lower

lake levels in the post-erosion period. During the low stage, exposed littoral sands reworked into aeolian dunes along windward shores; these evidence a major low stage within the last 600 years.

Sediment cores show an erosional hiatus stretching across the southern area of lake down to water depths of 121 m. This, coupled with desiccation cracks down to 121 m, is interpreted by Owen et al (1990) to mean a sharp 121 m or greater fall of the lake, and subsequent recovery, within the period between 1390 and 1860. The authors show that such a fall could occur within this interval if rainfall is reduced by only 30 to 50%, but historical evidence (section 3.2) suggests that the interval for this transgression/regression cycle would have been considerably shorter. Such rapidity of change in lake level and the desiccation of the Shire River, Lake Malombe and parts of Lake Malawi ought to have been so extreme as to warrant mention in the rich oral traditions of the region from this time, but such evidence is lacking. Moreover, T. Johnson (personal communication) finds no evidence in his Lake Malawi cores to indicate such a precipitous fall of the lake. Thus, such an extreme fluctuation is unlikely.

3.2. HISTORICAL INFORMATION AND LAKE LEVELS DURING THE LAST 600 YEARS

3.2.1. *Oral traditions of famines and droughts*

For the period post-dating the late Mawudzu high stand of Lake Malawi, several trends are apparent from sedimentary and archaeological records. These suggest a major decline of Lake Malawi beginning in the 15th century, possible recovery toward 1700, but otherwise persistence of the low levels and arid phase until the mid- or late 19th century. Further evidence of these fluctuations and their timing is presented in this section.

Information covering the 15th through 19th centuries comes from several sources, including oral traditions in the interlacustrine area to the north (Webster 1979a; Herring 1979), oral traditions of the Mutapa and other local peoples, and Portuguese documentary records (Webster 1979b). A fall in lake levels in the 15th century is supported by the historical traditions of drought. Although the genealogical dating of these episodes precludes precise knowledge of the times of occurrence, dates can usually be reliably established within two or three decades (Webster 1979b). Further back in time, there is less detail to the traditions and the droughts that do become part of oral history would have been particularly severe, creating much hardship among the peoples.

Much of the evidence derives from the East African "interlacustrine" region. That region extends from areas north of Lakes Albert and Kyoga to the southern end of Lake Victoria. Although it includes diverse conditions of climate, the region is homogeneous with respect to the interannual and interdecadal variability of rainfall. The Lake Malawi area is on the periphery of this climatic zone, but major droughts in that zone tend to extend as far south as Malawi (Nicholson 1987). Its levels correlate best with rainfall in this zone (see section 6). Webster (1979a) indicates that famines and droughts occurred in the interlacustrine region in the first decade of the fifteenth century, the 1430s and 1440s, and for a longer period beginning in the 1490s until about the 1530s. The area was relatively drought free between then and the late 16th century, when there appear reports of starvation, migration and the army crossing the Nile on bare ground during the generations 1580-1625. Arabic sources indicate that the Nile dried up in this region in 1621-1622. Reportedly half of the population of Egypt died then from starvation and disease. The lacustrine region was afterwards relatively drought-free until about the 1720s. Serious famines occurred then and in the 1750s, 1760s and 1780s (see Nicholson 1997). The last of these famines was particularly severe and was apparent throughout eastern Africa. It was followed by a decade of drought in the 1790s in southern Africa.

In areas closer to Lake Malawi there is specific evidence of drought during the 15th and 16th centuries. In the area northeast of the lake, the Mgulube experienced a three-year drought from 1561 to 1563. There was a great drought in the Mutapa empire within the period 1450 and 1480. This drought may have provided the impetus for Phiri migration to the Lake Malawi littoral (Webster 1979b), but the migration cannot be precisely dated and droughts that occurred in the 1400s and 1410s may have instead been a factor.

Webster's work suggests that the most important famines and droughts that affected the Lake Malawi region occurred in the 1580s, the 1620s and the 1720s. Famine and drought also because a common occurrence throughout the latter half of the 18th century. There was a notable absence of occurrences between the 1620s and 1720s. This chronology suggests that if a second peak in lake levels occurred during the late Mawudzu (Crossley et al. 1984), it would have been sometime between the 1630s and 1710s. This would place it as roughly coincident with the Lake Chilwa maximum (section 4) sometime within the period 1650 to 1750 A.D.

The record of the Nile flow (Toussoun 1925; Lamb 1966) measured at the Rodah gage in Cairo since 641 A.D. lends credence to the preceding scenario. The gage measurements provide an imperfect record of both the Nile flood and the summer minimum flow (Popper 1951), but the latter provides a reasonable indication of trends in equatorial rainfall. A more detailed analysis and a discussion of links to the African lakes appears in Nicholson (1997). The Nile record confirms the dry conditions in the early 15th century and then again beginning in the 1530s. This low stage is supported by a core from Lake Victoria (Stager et al. 1997) indicating a long arid interval commencing roughly about this time. The Nile flow also suggests relatively wet conditions from the 1630s to the 1710s, although the record is quite incomplete during this period.

The series of droughts that occurred late in the 18th century marked a trend towards increasing aridity that accelerated in the 1790s and resulted in a long arid interval throughout most of the early 19th century. Such a trend is evident throughout most of Africa (Nicholson 1995); its occurrence in southern Africa is detailed by Nicholson (1981). Evidence of its impact on Lake Malawi is described in 3.2.2; historical information related to rainfall, famines and droughts is examined in section 5.

3.2.2. *Period of low lake levels commencing toward 1800*

Historical references beginning around 1800 have been summarized into a lake chronology in Appendix A. The records show that Lake Malawi was unquestionably low throughout most of the first few decades of the 19th century and probably towards the end of the previous century as well An interesting reference indicative of a prolonged period of lower lake levels, in agreement with the sediment record, comes from Swann (1894). In 1892 and 1893 he noted "gigantic" trees standing some 3 feet deep in lake water. Known growth rates of the trees suggest a period of low levels lasting at least 50 to 100 years. This span probably included the late 1700s and early 1800s. Traditions of severe droughts and dried rivers also date to about that time. The location of villages, later flooded, suggests the lake stood at least 9 m below modern levels (Owen et al. 1990).

Other information suggests the persistence of this low stage during the 1820s, 1830s and 1840s. There are numerous reports of people traversing on foot formerly dry sections of the current lake, and of drying of the Rukuru River, as well as references to a much smaller lake and drought–induced tribal fighting and migrations. The lake gradually rose from around the late 1840s to the end of the next decade, at which time reports from European explorers become available.

There is corroboration from other lakes of the pronounced early 19th century arid interval. Lithological evidence in Lakes Chilwa (see next section) and Chiuta, about 100 km to the southeast, indicates that both lakes dried out during the period before 1850 A.D. (Owen and Crossley 1990). Although both lakes are shallow, considerable aridity would have been required for complete desiccation.

3.2.3. *Higher lake levels of the late 19th century and subsequent recession*

Lake Malawi maintained a relatively high stand from the late 1850s until the 1890s, with brief falls in some years. However, it had begun to recede in the mid-1870s. A dramatic decline occurred after ca. 1895 and the lake again reached and maintained very low levels throughout the early 20th century (Appendix A).

The stand of the lake in the 1860s is well established from reports of European travelers such as Livingstone and Kirk. Lake levels of the early 1860s can even be quantified on the basis of soundings made in Lake Malombe, which is hydrologically continuous with Malawi at moderate and high levels. A subsequent rise is attested by villages subjected to regular flooding during the 1870s. A subsequent decline was documented through measurements by the missionaries at Livingstonia and verified by numerous reports of visitors. The lake probably reached a maximum around 1875 or 1876.

Figure 4 shows the lake chronology beginning in 1800. The range of fluctuations during the last century has been about 5 meters, with conditions since the 1930s having been quite similar to those in the mid-19th century. Although during the 20th century the development of a sand bar has elevated Malawi's levels, its effect is small in comparison to the range of fluctuations exhibited by the lake.

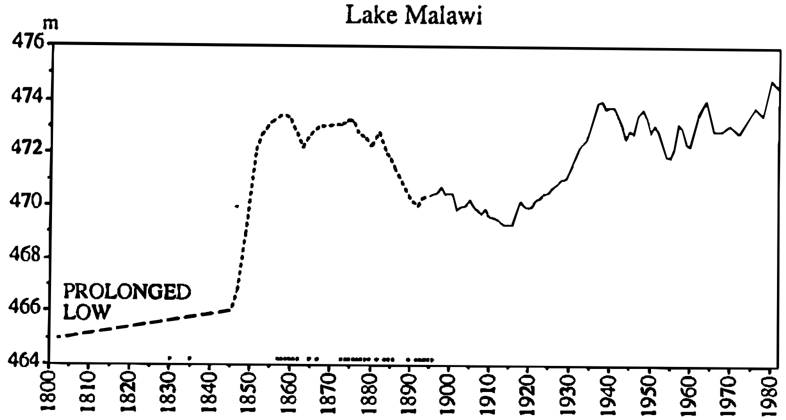

Figure 4. **Fluctuations of Lake Malawi since 1800 based on historical and geographical information and, beginning in 1896, modern records. Long-dashed lines indicate general periods of low levels; short-dashed lines indicate trends based on proxy data; solid lines indicate the modern lake record. Modern data are corrected for build-up of a sand bar in the lake. Years for which specific references are available are indicated at the bottom with dots.**

4. Lake Chilwa

Lancaster (1979) and Crossley et al. (1984) present historical evidence of levels of Lake Chilwa back to the early 1800s. Theirs and other information on the lake levels is summarized in the chronology in Appendix B. Missionaries indicated that the lake was dry in the early 1900s, as it seems to have been also in the 1940s. Chilwa was also dry more recently in 1968 and 1973. Around 1870 there was probably a brief low phase, with a prolonged low phase prior to ca. 1850. Lake Chilwa was high at the time of Livingstone's visit (1859); Lancaster suggests its level exceeded that of its modern 1978 peak, but Crossley et al. suggest that it did not.

Lake Chilwa probably maintained a prolonged low-level in the early 1800s. Evidence of that low stand includes a well-mixed, sandy clay, hard pan layer in sediment cores from the lake and an account that around 1900 one could walk across the dried lake floor to Nchisi Island, occasionally breaking through crust to ankle deep mud and a hard surface below. That hard surface would correspond to the hard layer in the cores and would represent a long arid interval. Based on the depth of the mud, the probable thickness of the 1903 crust, and estimated sedimentation rates, Crossley et al. (1984) suggest that it would have taken some 50 to 100 years to accumulate these sediments. This would suggest that the dry phase represented by the hard layer in the cores probably ended between 1800 and 1850. The degree of mixing in the hard layer indicates that the arid interval it represents was far more prolonged than any that occurred within the last 100 years.

There is a Yao tradition, reported by the headman Chendombo, of a very great drought and famine when the Mang'anja fled to the river (presumably Shire River) to escape the invading Yao (Stegman 1953). This would have occurred during the raids of the 1860s (Ajayi 1989) and fits with documentary reports of droughts in the 1860s (Webster 1979b). Another Yao tradition of this period states that Lake Chiuta nearly dried up during a great famine and drought. This would also imply at least a brief period of low levels of Lake Chilwa, something reported by Owen et al. (1990) as occurring around 1870. A brief recession of Lake Malawi also occurred in the 1860s, coincident with these droughts and the desiccation of Lake Chiuta.

Evidence of a recent high stand is beach gravel around the lake margin at a height of 631 m, 9 m above modern levels of the lake. This beach has a radiocarbon date of 160 B.P. (ca. 1750 A.D.). A lake of this depth would represent rainfall some 35 to 40% higher than at present. The recent date of this high stand is confirmed by archaeological evidence, including ceramic traditions and recent trade beads in sediment just below the gravel layer. It is also confirmed by the longevity of baobab trees near the lake, because the trees are killed rapidly by floods. Many trees have an age of 350 years, indicating growth extending back to 1650 A.D. or earlier in areas above 631 m, the old shoreline height, as shown by beach gravel. No tree in the lower areas has an age greater than 225 years, hence indicating no growth prior to ca. 1760 A.D. This suggests that the lower areas were flooded prior to 1760 and, thus, that the high stand at 631 m occurred some time between 1650 and 1750 A.D.

The beach gravel around the lake has been reworked so it is hard to get good evidence on the number and height of earlier high stands. Lake Chilwa probably had repeated pre-Iron Age high stands (pre-18th century). Evidence suggests a stand similar to today's (624 m) during part of the early Iron Age, perhaps around the 10th century (Shaw et al. 1984).

Figure 5 shows the chronology of Lake Chilwa since 1800. Although many similarities with the trends of Lake Malawi (Fig. 4) are apparent, there are some notable differences. Both lakes were extremely low or desiccated throughout most of the first half of the 18th century and rose to relatively high levels in mid-century. However, while Malawi retained these levels until the 1880s, a relatively major decline of Chilwa appeared to have occurred in the late 1860s, with low stands maintained until around 1870. The analogous fluctuation in Lake Malawi was of lower magnitude and shorter duration. Trends in the lakes remained similar until the 1930s: a rapid decline occurred in the 1880s, the lakes were relatively low during the 1890s and early 20th century, and the lakes began to rise in the 1920s, reaching maxima in the late 1930s. Both lakes experienced declines in the 1940s, but from the 1950s on the fluctuations of the lakes were in rough opposition. Chilwa was high in the 1950s, low in the 1960s and high in the 1970s, consistent with rainfall fluctuations occurring in the subtropics of the southern hemisphere at this time (Nicholson 1995). Levels of Lake Malawi follow the opposing pattern of rainfall in equatorial regions during these decades.

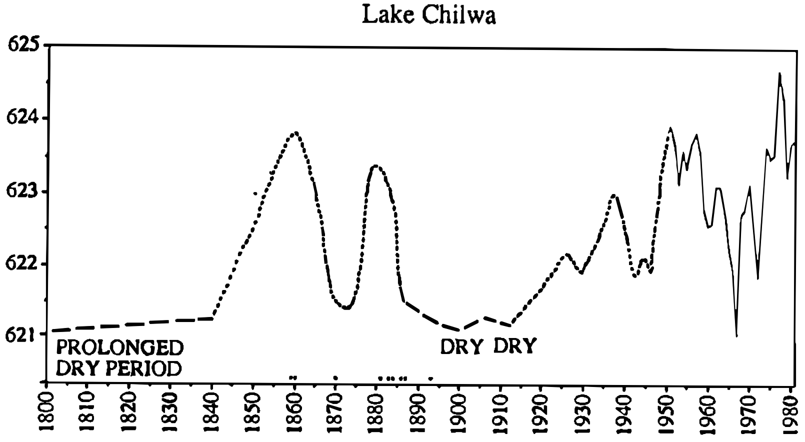

Figure 5. **Fluctuations of Lake Chilwa since 1800, based on historical and geographical information and, beginning in 1949, modern records. Long-dashed lines indicate periods of low levels; short-dashed lines indicate trends based on proxy data; solid lines indicate the modern lake record. Years for which specific references are available are indicated at the bottom with dots.**

5. Recent historical record of famines and droughts

The records of famines, droughts and other climate-related phenomena have been summarized in the form of chronologies for Malawi (Appendix C) and for areas of Mozambique (Appendix D) and Zambia/Zimbabwe (Appendix E) where the interannual variability of rainfall is well correlated with conditions in Malawi. While the chronology for Malawi is vague and generalized, numerous specific references are available for the other areas. Although many of the trends of the lakes parallel variations in rainfall conditions, as indicated by the famine and drought record, much of the time the lakes (particularly Malawi) show quite independent fluctuations.

Drought conditions commencing late in the 18th century are apparent, particularly in the 1790s. Likewise there is substantial evidence of a prolonged period of aridity, with frequent and severe drought, throughout at least the 1820s and 1830s, and possibly the 1840s. This period is evident in all three chronologies in Appendices C, D, and E, and it coincides with prolonged low phases of both Malawi and Chilwa. The period of aridity is evident in other Rift Valley lakes as well and throughout most of Africa (Nicholson 1995).

In the 1850s and 1860s, when lake levels were generally high, drought and famine occurred frequently in Malawi and northern Mozambique. The evidence for this includes the reliable witness of Livingstone (1875) and others. There is, however, a small recession of Lake Malawi during the 1860s, coincident with the most severe droughts, and Lake Chilwa began to recede, reaching a low level somewhere around the 1870s. Droughts also occurred during the lake maximum of the early and mid-1870s, but were infrequent during the time of the lake's recession from 1875 to at least 1886.

TABLE 1. Correlations between rainfall in select regions shown in Fig. 6 and the levels of Lakes Chilwa and Malawi.

	ST	ZM	NMZ	M	SM	WMZ	SMZ	ZM
Malawi	0.44	-0.05	0.10	0.20	-0.30	0.33	0.14	0.13
Chilwa	-0.10	0.18	-0.04	-0.04	0.25	0.00	-0.10	0.30

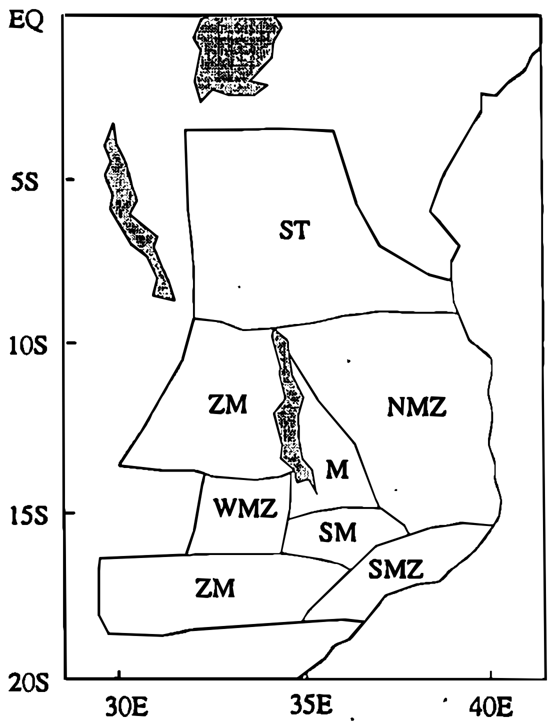

Figure 6. **Map of rainfall regions correlated with lake levels. ST= southern Tanzania, ZM= Malawi/eastern Zambia, M= Malawi, SM= southern Malawi, SMZ= southern Mozambique, NMZ= northern Mozambique, WMZ= western Mozambique, ZM = Zimbabwe/Mozambique.**

6. Relationship between lake-level fluctuations and rainfall

Lack of correspondence between records of famine and drought and trends in the levels of Lakes Malawi and Chilwa suggest the need for further assessment of the response of the lakes to rainfall fluctuations. To a first approximation, each lake is assumed to respond to the average rainfall over its catchment. It is questionable, however, to what extent these catchments reflect conditions on a broader scale, such as large regions within southern or eastern Africa. For Malawi, the question is complex because rainfall anomalies are frequently of opposite sign in the northern and southern portions of its catchment. Its levels likely reflect conditions to the north, over highlands where rainfall is substantially higher than in the southern lake area.

The relationship between rainfall variability and lake level is examined using rainfall from an archive described in Nicholson (1986). The modern lake records, commencing in 1896 for Malawi and 1949 for Chilwa are correlated with rainfall in the eight homogeneous regions shown in Figure 6. The results are shown in Table 1.

Lake Malawi is correlated with rainfall in only two regions: western Mozambique and southern Tanzania. The correlation coefficient with western Mozambique, 0.33, is significant at the 95% level. That for southern Tanzania, 0.44, is significant at the 99% level. The commonality of these two regions is that both include considerable areas of highlands with extreme rainfall conditions. Presumably the same factors that control rainfall in these highland regions control rainfall over the lake itself. This seems reasonable, because of the presence of local mountain-lake circulation systems that produce mesoscale patterns of rainfall over the lake (Hastenrath 1988). Also, stream flow from the higher regions affects lake levels.

Lake Chilwa is best correlated with rainfall in two regions: southern Malawi (0.25) and western Mozambique (0.30). However, neither correlation reaches the 95% significance level. The rainfall correlation is much lower than in the case of Lake Malawi. This probably reflects local influences on this small lake that are independent of those in larger-scale regions. Correlation between Lakes Chilwa and Malawi is 0.18 (n.s.) for the period 1949 to 1981. The relatively low degree of correlation reflects independent fluctuations, particularly high frequency fluctuations, of the lake during many intervals. Over the longer term the lake curves are considerably more similar than during the 1949 to 1981 period (see section 7, Fig. 7).

Despite relatively low correlations, it is apparent that the lake records mimic rainfall conditions when conditions prevail over very large areas. In particular, the correspondence is good when similar conditions arise in both eastern equatorial and southern Africa.

Owen et al. (1990) produced a simple water balance model for Lake Malawi and estimated the rainfall variations needed to account for a recession/transgression cycle with a 110 m change in lake level within historical times. They concluded that such a change could be accomplished with a change in rainfall on the order of 50%. Much smaller changes could account for the fluctuations shown in Figures 3 and 4.

7. Summary and Conclusions

Synthesis of sedimentary, geographical and historical information presents a fairly detailed picture of the fluctuations of Lakes Malawi and Chilwa since about 1800. Low

lake levels prevailed during most of the first half of the 19th century while high levels generally prevailed during the mid- and late-19th century. Maxima were reached in the 1870s, but the lakes remained high in the early 1880s. A decline then occurred that culminated in low stands throughout the early twentieth century, with a return to higher lake-levels in mid-century. Highest recent levels occurred in the 1970s. Except for that maximum, these trends closely parallel those in other subtropical areas of Africa (Nicholson 1995), although the decline late in the 19th century may have commenced earlier here than elsewhere over Africa.

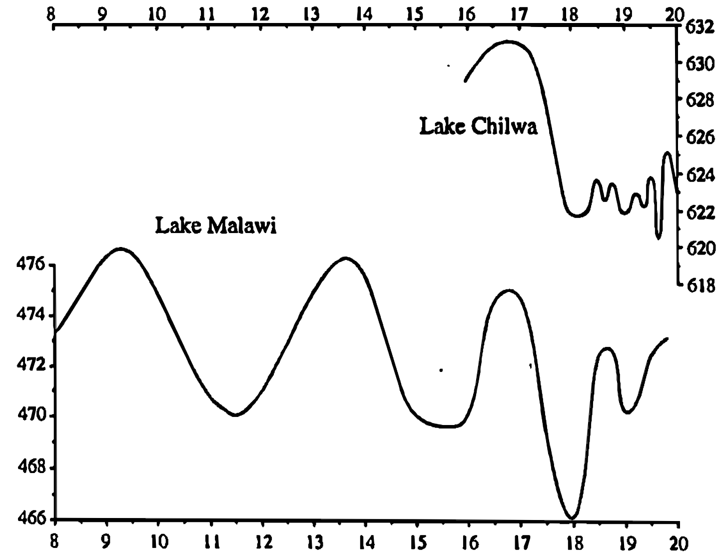

Figure 7. **Long-term fluctuations of Lakes Malawi and Chilwa.**

The long-term chronologies of Lakes Malawi and Chilwa are presented in Figure 7, based on information in the text and the lake chronologies in Appendices A and B. The long-term history of the lakes is reasonably similar, with high stands toward 1700, then a decline to comparatively low modern levels. The detailed historical information available to complement sedimentary and archaeological records of Malawi suggests a secondary maximum toward 1700 that is roughly coincident with the maximum of Lake Chilwa at that time. This is consistent with the suggestion of Owen et al. (1990) that the late Mawudzu high stand was a double peaked event.

It appears that lower frequency fluctuations of these lakes are roughly in phase, but that higher frequency fluctuations are often out of phase. Extreme dry periods, with major falls of the lakes, tend to occur synchronously in both lakes.

Independent higher frequency fluctuations reflect the geographical differences in the conditions of rainfall influencing lake levels. Lake Malawi is better correlated with rainfall to the north of the lake, in southern Tanzania, than in other areas surrounding the lake. However, local forcing is also apparent. Correlation analysis suggests than Lake Malawi is a better indicator of rainfall conditions in equatorial East Africa than in the outer-tropical latitudes in which it lies. Lake Chilwa instead appears to respond to relatively local conditions of rainfall. The complex climate dynamics governing the levels of these lakes underscores the difficulty in interpreting their histories in climatic terms. A more reliable interpretation can be gleaned from the collective histories of the East Africa Rift Valley lakes, rather than from any individual lake.

8. Acknowledgments

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9. References

Ajayi, J. F. A., 1989. General History of Africa. University of California Press.

Brueckner, E. 1890. *Klimaschwankungen seit 1700*. E. Holzel.

Butzer, K. W., G. L. Isaac, J. L. Richardson, and C. Washbourne-Kamau. 1972. Radiocarbon dating of East African lake levels. Science **175**: 1069-1076.

Crossley, R., S. Davison-Hirschmann, R. B. Owen, and P. Shaw. 1984. Lake level fluctuations during the last 2,000 years in Malawi, p. 305-316. *In* J. C. Vogel [ed.], Late Cainozoic palaeoclimates of the southern hemisphere. Balkema.

Crossley, R., and S. Davison-Hirschmann. 1981. Hydrology and archaeology of Lake Malawi and its outlet during the Iron Age. Palaeoecology of Africa **13**: 123-126.

Curtin, P., S. Feierman, L. Thompson, and J. Vansina. 1978. African History. Little Brown and Company.

Dixey, F. 1924. Lake level in relationship to rainfall and sunspots. Nature **114**: 659-661.

Drayton, P. 1979. Study of the causes of the abnormally high levels of Lake Malawi in 1979. Technical Report No. 5, Malawi Government, Water Resources Division.

Eccles, D. H. 1974. An outline of the physical limnology of Lake Malawi (Lake Nyassa). Limnology and Oceanography **18**: 730-742.

Fisher, H. 1974. Presented at the African History Seminar, School of Oriental and African Studies. Unpublished manuscript, University of London.

Hastenrath, S. L. 1988. Climate and Circulation of the Tropics. Reidel.

Herring, R. S. 1979. Hydrology and chronology: The Rodah nilometer as an aid in dating interlacustrine history, p. 39-86. *In* J. B. Webster [ed.], Chronology, Migration and Drought in Interlacustrine Africa. Africana Publishing Company.

Johnston, H. H. 1897. British Central Africa. Metheun.

Kirk, J. 1865. Meteorological tables illustrating the climate of eastern tropical Africa. Proceedings of the British Meteorological Society **11**: 22.

Kraus, E. B. 1955. Secular changes of tropical rainfall regimes. Quarterly Journal of the Royal Meteorological Society **81**: 198-210.

Lamb, H. H. 1966. Climate in the 1960s. Geographical Journal **132**: 183-212.

Lancaster, N. 1979. The changes in the lake level, p. 27-34. *In* M. Kalk, A. J. McLachlan, and C. Howard-Williams [eds.], Lake Chilwa: Studies of Change in a Tropical Ecosystem. Monographae Biologicae 35, Junk.

Liesegang, G. 1978. Famines and Smallpox in South Eastern Africa 18th to 20th Centuries. Unpublished manuscript, Universida de Eduardo Mondlane, Maputo, 12 pp.

Livingstone, D. 1875. A Popular Account of Missionary Travels and Researches in South Africa. John Murray.

Livneh, A. 1974. Some notes on drought, famine and pestilence in Rhodesia. Unpublished manuscript, presented at the African History Seminar, School of Oriental and African Studies, University of London, 3 p.

Mohr, E. 1876. To the Victoria Falls of the Zambezi. Books of Rhodesia.

Nicholson, S. E. 1976. A climate chronology for Africa: synthesis of geological, historical and meteorological information and data. Ph.D. Thesis. Department of Meteorology, University of Wisconsin, Madison.

Nicholson, S. E. 1981. The historical climatology of Africa, p. 249-270. *In* T. M. L. Wigley, M. J. Ingram, and G. Farmer [eds.], Climate and History: Studies on Past Climates and Their Impact on Man. Cambridge University Press.

Nicholson, S. E. 1986. The spatial coherence of African rainfall anomalies - interhemispheric teleconnections. Journal of Climate and Applied Meteorology **25**: 1365-1381.

Nicholson, S.E. 1987. The nature of rainfall variability in Africa south of the equator. Journal of Climatology **6**: 515-530.

Nicholson, S. E. 1995. Environmental Change within the Historical Period, p. 60-75. *In* A. S. Goudie, W. M. Adams, and A. Orme [eds.], The Physical Geography of Africa. Oxford University Press.

Nicholson, S. E. 1996. A review of climate dynamics and climate variability in eastern Africa, p. 25-56. *In* T. C. Johnson and E. Odada [eds.], The limnology, climatology and paleoclimatology of the East African lakes. Gordon and Breach.

Nicholson, S. E. 1998. Historical fluctuations of Lake Victoria and other lakes in the northern Rift Valley of East Africa, p. 7-35. *In* J. T. Lehman [ed.], Environmental change and response in East African lakes. Kluwer.

Owen, R. B., and R. Crossley. 1990. Recent sedimentation in Lakes Chilwa and Chiuta, Malawi. Palaeoecology of Africa **20**: 109-117.

Owen, R. B., R. Crossley, T. C. Johnson, D. Tweddle, I. Kornfield, S. Davison, D. H. Eccles, and D. E. Engstrom. 1990. Major low levels of Lake Malawi and their implications for speciation rates in cichlid fishes. Proceedings of the Royal Society of London B **240**: 519-553.

Pike, J. G., 1965. The sunspot-lake level relationship and the control of Lake Nyasa. Journal of the Institute of Water Engineers **19**: 221-226.

Popper, W. 1951. The Cairo Nilometer. University of California Press.

Roberts, A.D., 1974. A note on drought, famine and pestilence in and around Zambia. Unpublished manuscript, presented at the African History Seminar, School of Oriental and African Studies, University of London.

Shaw, P., R. Crossley, and S. Davison-Hirschmann. 1984. A major fluctuation in the level of Lake Chilwa, Malawi, during the Iron Age. Palaeoecology of Africa **16**: 391-395.

Sieger, R. 1887. Schwankungen der innerafrikanischen Seen, p. 41-60. *In* Vereinigung der Geographie Jahresbericht. University of Vienna.

Spigel, R. H., and G. W. Coulter. 1996. Comparison of hydrology and physical limnology of the East African Great Lakes: Tanganyika, Malawi, Victoria, Kivu and Turkana, p. 103-140. *In* T. C. Johnson and E. Odada [eds.], The limnology, climatology and paleoclimatology of the East African lakes. Gordon and Breach.

Stager, J. C., B. Cumming, and L. Meeker. 1997. A high-resolution, 11,400-year diatom record from Lake Victoria, East Africa. Quaternary Research **47**: 81-89..

Stegman, J. J. 1953. Nyasaland droughts. Nyasaland Journal 4: 67-69.

Swann, A. 1894. Two African Lakes. British Central Africa Gazette 1 October: 2.

Toussoun, O. 1925. Memoire sur l'histoire du Nil. Memoire de l'Institut d'Egypt, vol. 9. Cairo: Français de l'Archaéologie Orientale.

Webster, J. B. 1979a. Noi! Noi! Famines as an aid to interlacustrine chronology, p. 1-38. *In* J. B. Webster [ed.], Chronology, Migration and Drought in Interlacustrine Africa. Africana Publishing Company.

Webster, J. B. 1979b. Drought and migration: the Lake Malawi Littoral as a region of refuge, p. 148-157. *In* M. T. Hinchey [ed.], Botswana Drought Symposium. The Botswana Society.

APPENDIX A. Long-term chronology of Lake Malawi

15th and 16th centuries

Frequent famines and droughts in the interlacustrine region, approximately dated to the 1430s and 1440s and from about the 1490s to 1530s (Webster 1979a, 1979b). The Nile was low in the early 15th century and again in the 1530s. The region was relatively drought free from about the 1540s to the 1570s. Reports of drought, starvation and exceedingly low Nile levels occurred again in generations from ca. 1580 to 1625.

In closer proximity to Lake Malawi, periods of severe droughts included the 1400s and 1410s, sometime within the period 1450 to 1480, and in the 1560s, 1580s and 1620s.

These reports collectively suggest relatively low lake levels, particularly in the early 1400s, the mid-15th century, the early 16th century, the late 16th century, and the very early 17th century.

17th and early 18th centuries

The interlacustrine region was relatively free of drought and famine free; Nile flow was relatively high from about the 1630s to the 1710s. The Lake Malawi region was also relatively drought free from then until the 1720s. This suggests relatively high lake levels within these intervals.

Late 1700s to early 1800s

Swann, between 1892 and 1893, noted "gigantic" trees standing in about 3 feet of water (Owen et al. 1990). The lake then stood at 470 m, lowest since Livinstone's visit of 1861. Trees suggest that some time before 1860, Lake Malawi was at a continuously lower level than 469 m for a long period. On basis of known growth rates of trees, the minimum period of continuous low levels must have lasted 50 to 100 years, which probably includes the late 1700s and early 1800s.

Traditions referring to severe droughts and dry rivers persist in the region from the early 1800s back to the late 18th century (Owen et al. 1990).

Early 19th century

Location of villages suggests lake levels at least 9 m below modern levels (Owen et al. 1990).

Chief Moses Ngosi, born around 1885, said that in much earlier times there was a village an hour's walk lakeward of the present Ruasho River delta. The site probably refers to a shoal area, which could only be reached on foot if the lake had been at least 9 m below modern levels (Owen et al. 1990).

ca. 1825 Johnston (1897) records a tradition that "some 70 year ago (i.e., about 1825) the north end of the lake became so shallow between Deep Bay and Amelia Bay that a chief and his men waded across it where it is now many fathoms deep" (Owen et al. 1990).

ca. 1820s Ngonde king Mwangonde, whose reign genealogically dated to about 1815 to 1835, walked across the northern part of Lake Malawi to marry a woman (Owen et al. 1990).

The North Rukuru River in northern Malawi dried up during the reign of Mwangonde (ca. 1815-1835) (Owen et al. 1990).

There was a general view that widespread aridity in the late 1820s was a cause of the Yao dispersal towards the southern lake area (Owen et al. 1990).

Stewart visited the lake in 1879 and spoke of flooding of a small land area that stood in the mouth of the Rukuru river some 60 yr previous. Although a change in the river could account for its flooding, this is consistent with other evidence of drier conditions, including the above reference to the Rukuru drying up (Sieger 1887).

1830 Low level (Nicholson 1976).

1835 The Ngoni Gama clan of northern Malawi, the followers of Zwangendaba (Curtin et al. 1978) have a tradition of crossing the Zambezi near Zumbo on a sandy causeway in the dry season of 1835 (date established via reference to a solar eclipse; Owen et al. 1990).

1830s Dixey reported very low levels for the 1830s, but gives no source of information (Owen et al. 1990).

Further south, tribal chief Amapunda walked across dry ground to Likoma Island at north end. Tribal chronology suggests his reign was approximately the 1830s (Owen et al. 1990).

1840s Informant at Chikowa's village near Mawudzu Hill on SE arm of lake, born ca. 1910, said her father's village had once been close to Boadzulu Island "when the lake was small" about the time of "fighting between the Yao and Ngoni". She may refer to period of alliance between the Msamala Yao and the Nyanja against the Ngoni around the 1840s. Since water near the island is now about 40 m deep, the report implies very low levels in 1840s (Owen et al. 1990).

References to tribal fighting ca. 1840s indicate very low lake levels (Owen et al. 1990).

late 1840s to late 1850s

Probably a gradual rise of Lake Malawi (Sieger 1887).

1857-63 Very high levels (Nicholson 1976)

1859 The lake had a relatively high stand when Livingstone visited because the missionaries found no evidence of formerly higher stands. Also the Shire was a broad and deep current (Sieger 1887). No evidence that the lake rose or fell much; Livingstone suggested the fluctuations did not exceed 3 or 4 feet. Stewart's report from 1879 suggested fluctuations of similar magnitude (Sieger 1887).

Evidence that the lake rose subsequently comes from descriptions of flooded villages in later years (see 1878 and 1879).

1860 Peak level is based on the coincidence between lake level deduced from Livingstone's soundings in Lake Malombe in 1861 and Dixey's (1924) report of marks, presumably aquatic algal lines, on lakeshore rocks up to that level (Owen et al. 1990).

1863 Level based on sounding by Kirk in Lake Malombe because that lake, when at moderate to high levels, is virtually identical to Lake Malawi (Owen et al. 1990).

1865 High stand according to Livingstone (Lamb 1966; Pike 1965). Remained relatively higher until about 1880.

1867 Drop in lake levels (Pike 1965; Owen et al. 1990)

1873 High lake level (Nicholson 1976)

1874 Young spoke of high water level of the Shire River (Sieger 1887).

1875-85 At the time of Laws in 1878 the lake was in recession; he traversed large stretches that had previously been underwater even during the dry season. Rivers along the plain he crossed dried up before reaching the lake. Recession of the lake was confirmed by measurements of missionaries at Livingstonia, showing a drop of 3 feet between December 1875 and December 1880. The level was so low as to pose a risk to ships on the southern end of the lake and on the Shire River. Although by about 1886 the lake appears to have lacked an outlet, both Livingstone in 1875 and Young in 1876 argued vigorously for the existence of an outlet, which was even mentioned by name by the natives (Sieger 1887). The outlet appears to have been lost in about 1886. Brueckner (1890) and Sieger (1887) suggest that the maximum stand of Lake Malawi occurred in 1875.

1875 Lake level falling (Nicholson 1976).

1876 Lake level falling (Nicholson 1976).

1876 Appears that a big fall occurred in 1876 (Sieger 1887), immediately after maximum stand. Later maps of Stewart, Kerr and Johnson showed shifts from islands to peninsulas, compared to earlier maps, indicating desiccation.

1877 Lake level very low and falling; apparently deficient rainfall in the region (Nicholson 1976).

1878 Laws reported in autumn of 1878 that the village of Matetes was so low-lying that the water from the lake covered the village nearly to a man's height during nearly every rainy season, driving away its inhabitants. This implies a much higher lake level than when the village was established.

Nevertheless, lake level was very low and falling compared to more recent years; apparently deficient rainfall in the region.

1879 Stewart reported the village of Karongas was covered by deep lake water during the rainy season, driving away its inhabitants (Sieger 1887).

1882 High lake level (Nicholson 1976).

End of 1870s to 1886

Recession of Lake Malawi (Sieger 1887).

1884 Kerr could see continued recession of the lake via drying of rivers that previously held much water and drying of land along the Shire and Pamalomba. The level of the lake was apparently already a few feet lower than during Livingstone's time (Sieger 1887).

1885 Moir confirmed the lowering of the lake also in 1885.

1886 Last mention of seeing sand and mud surfaces that had previously been covered by water of the lakeshore. This is the year that the lake apparently lost its second (northern) outlet.

1890 Very low level of the lake (Nicholson 1976).

1892-93 Swann, between 1892 and 1893, noted "gigantic" trees standing in about 3 feet of water (Webster 1979b). The lake stood at 470 m, lowest since Livingstone's visit of 1861.

1892-95 In these four years, the lake was rising rapidly (Nicholson 1976).

1896 to 1915

Steady decline of the lake (Nicholson 1976).

Early 1800s

Prolonged low level (Lancaster 1979; Crossley et al. 1984; Owen et al. 1990). Dry phase probably ended between 1800 and 1850.

Lake Chiuta almost dried up during reign of some king - probably indicates low levels of Chilwa as well (Webster 1979b).

Lithological evidence that both lakes dried out for long period prior to ca. 1850 (Owen and Crossley 1990).

pre-1850 Prolongued low phase prior to this (Owen et al. 1990)

1859 Lake was high at time of Livingstone's visit (Owen et al. 1990). However, he indicated the lake water tasted weakly bitter, indicating relatively high salt content and levels below maximum, when the basin contains fresh water (Sieger 1887).

Lake was apparently lower in 1859 than during the time of Burton's visit (1857/58), because he reported the water tasted fresh (Sieger 1887).

1860 Lake was high, according to Brueckner (1890).

ca. 1870 Brief low phase (Owen et al. 1990).

1881 Johnson assumed the lake basins to the north (apparently Lakes Chiuta and Amamba) were continuous with Chilwa. If so, this would indicate a high stand of the lake (Sieger 1887).

1883 O'Neill discovered that Lakes Chiuta and Amamba were separated from Chilwa by a 4.5 to 9 m wooded drainage divide, but indicated they may have been connected in some years, although natives said this had not been so in recent memory (Sieger 1887).

1884 Lake level was high (Brueckner 1890).

1886 Last found that water flowed between the lakes during the rainy season. He mentioned a decline of Chilwa levels since the beginning of the 1880s, presumably referring to differences in the observations of Johnson and O'Neill (Sieger 1887).

ca. 1886 The lake was in recession (Sieger 1887). He indicated it had been in recession since probably the end of the 1870s.

1887 Lake level was comparatively low, compared to 1884 and 1860 (Brueckner 1890).

Early 1900s

Missionaries indicated the lake was dry (Owen et al. 1990). In 1903 one could walk across the dry lake bed to Nchisi Island.

1968 and 1973

Low levels of the lake (Owen et al. 1990).

late 18th century/early 19th century

Rainmakers were called to Nkamanga (Rumphi area, northern Malawi) during a severe drought in the time of the first Mlowoka or his son (about 1780-1840). This may have been about the time Lake Rukwa dried up, ca. 1770 (Owen et al. 1990).

Kalinga records an increase in immigration from the highlands to the northeast of the lake into the Ngonde region of the lake shore, perhaps partly attributable to drier conditions, between 1740 and 1840 (Owen et al. 1990).

late 1790s

Raiding from Makua into Yao territory in the 1790s caused by drought (Webster 1979b). The Mahlatule famine of ca. 1799-1803 caused the Yao (NE Zambia, NW Mozambique) to disperse into the Malawi region.

1820s General view that widespread aridity in the late 1820s was a cause of the Yao dispersal towards the southern lake area (Owen et al. 1990).

early 1860s

Drought in Malawi produced chaos that was a major factor in the failure of the UMCA Magomero Mission (Webster 1979b).

1860s Chendombo, a Yao headman, indicated that a severe drought occurred when the Mang'anja fled to the river from invading Yao (Webster 1979b). Crops had been planted and were growing well when the drought occurred and killed them.

There is a Yao tradition from this period that Lake Chiuta almost dried up and that there was a very great drought and famine (Webster 1979b).

APPENDIX D. Historical chronology of famines, droughts and related phenomena in Mozambique

ca. 1714 Drought in Changamire's territory (Liesegang 1978).

1744-45 Drought and famine in the Zumbo area (region 57) (Liesegang 1978).

1758 In 1758 the gold washeries of Mixonga north of Tete had to be abandoned for a few years because the workers could not be fed (Liesegang 1978).

1759 Immediately before this year there was widespread drought in the Zambezi Valley and in neighboring areas; the usual Zambezi flood in the delta failed to appear (Liesegang 1978).

1794-98 Drought produced famine at Tete (16.5S 33.5E; Roberts 1974).

1822-30 Famine apparently induced by low rainfall near Sena (18S 36E) where agriculture was largely dependent on rainfall (Liesegang 1978). Drought in some years in Inhambane.

1828-29 Hunger induced most inhabitants of Sena (18S 36E) to abandon their town (Liesegang 1978). Groups of warriors from Barue and neighboring areas were looking for food. Problem probably extended to Sofala, as well, as grain was shipped there from Mozambique.

1844-45 Famine in Sofala (20S 35E) (no cause given) in 1844 and a drought in the beginning of 1845 (Liesegang 1978).

1854 Famine at Sena (18S 36E) in January and, according to Livingstone, at Tete (16.5S 33.5E; Liesegang 1978).

1855 Adequate rainfall at Tete (16.5S 33.5E), according to Livingstone (1875). This appears to relate to the 1855-56 rainy season.

1856 Famine in Quelimane (18S 36E) supposedly helped cause increased slave trade (Liesegang 1978).

1858-60 Drought and famine at Tete (16.5S 33.5E), according to Livingstone. At Inhambane (24S 35.5E) in November 1858 drought forced the population to rely on seafood and wild fruits, and in the Limpopo Valley (23S 33E) there was drought and famine in 1859-60 (Liesegang 1978).

1860-61 Rainfall at Tete totaled 852 mm in this year (Kirk 1865).

1861-63 Drought caused famine at Tete (16.5S 33.5E; region 56), according to Livingstone, and affected also the Mang'anja of the middle Shire Valley (ca. 16S 35E; region 55); the lower Zambezi (18S 35.5E; region 58) was unusually low. In mid-1863 crop failure was reported for Limpopo (ca. 23S 33E; region 67) and Nkomati Valleys, probably from irregular rainfall and wars (Liesegang 1978).

1864-70 No droughts or famines documented (Liesegang 1978).

ca. 1871-73 Famine along the Nkuna and further south (Liesegang 1978).

1875 Madimgele famine (Liesegang 1978).

1880s No droughts or famines reported in this area (Liesegang 1978)

1903 Drought for the lower Buzi Valley (ca. 20.5S 33E), the area near Inhambane (24.5S 35.5E), and the eastern Transvaal (ca. 24S 30; region 68; Liesegang 1978).

1910-16 Deficient rainfall widespread; famine near Inhambane (24.5S 35.5E) in 1812 (Liesegang 1978).

1917-19 Great floods in the Sena (18S 36E) - Tete (16.5S 33.5E) region of the lower Zambezi, which caused prolonged famine and probably resulted from early rather than high floods (Fisher 1974).

APPENDIX E. Chronology of famines, droughts and related phenomena: Zambia and Zimbabwe.

1790s NE Zambia, food shortages among the Bisa (ca. 12S 32E) caused migration to the Chewa country, but this may be due to intense showers (Roberts 1974).

1800s Frequent famines in early 19th century (probably ca. 16S 24E, assuming this refers to the Lozi people), supposedly caused by war with the Lunda and Yeke (Roberts 1974).

1827-29 For three years about this time there was drought and famine in Zambia (Bemba country; ca. 12S 32E; Roberts 1974). Drought in present southeastern Zambia too.

The drought that plagued Mozambique and Zambia in these years seems to have affected at least the northeastern parts of the Rhodesian plateau (ca. 17S 31E; Livneh 1974; Roberts 1974). The Duma area experienced drought and severe famine (Liesegang 1978).

1827-31 The first recorded locust invasion (1827), possibly associated with droughts and famines in the entire period (probably ca. 16S 24E). Locusts need a low lake level in order to multiply (Roberts 1974). Around 1827 there was supposedly a year without rain, followed by a locust invasion.

1833-36 Drought in Bemba country (Zambia), probably propelled the Ngoni in their trek northward (Webster 1979b; Roberts 1964).

1845 Drought in Bemba country (Zambia), probably propelled the Ngoni in their trek northward (Webster 1979b; Roberts 1964).

1869 Mohr (1876) experienced much rain on his travels through Zimbabwe.

ca. 1879 Drought in northeastern Zimbabwe (ca. 17S 30E; Liesegang 1978).

1880s No droughts reported except for a minor one among the Duma (Zimbabwe) between 1886 and 1890 (Liesegang 1978).

Post 1883 Famine and drought near Salisbury (i.e., Harare, 17 49S 31 06E; Livneh 1974).

1887 Mazoe Valley (ca. 17S 32E) famine (Livneh 1974).

1893-96 Partial drought and locusts in Matabeleland (ca. 17S 30E; Livneh 1974).

1899 Severe drought over the whole of Zimbabwe (Livneh 1974).

1913-18 Drought in Zimbabwe (Liesegang 1978).