Report

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Climatic, Socio-economic, and Health Factors Affecting Human Vulnerability to Cholera in the Lake Victoria Basin, East Africa

Cholera epidemics have a recorded history in the eastern Africa region dating to 1836. Cholera is now endemic in the Lake Victoria basin, a region with one of the poorest and fastest growing populations in the world. Analyses of precipitation, temperatures, and hydrological characteristics of selected stations in the Lake Victoria basin show that cholera epidemics are closely associated with El Niño years. Similarly, sustained temperatures high above normal (Tmax) in two consecutive seasons, followed by a slight cooling in the second season, trigger an outbreak of a cholera epidemic. The health and socioeconomic systems that the lake basin communities rely upon are not robust enough to cope with cholera outbreaks, thus rendering them vulnerable to the impact of climate variability and change. Collectively, this report argues that communities living around the Lake Victoria basin are vulnerable to climate-induced cholera that is aggravated by the low socioeconomic status and lack of an adequate health care system. In assessing the communities' adaptive capacity, the report concludes that persistent levels of poverty have made these communities vulnerable to cholera epidemics.

INTRODUCTION

In East Africa, a cholera epidemic was first reported in 1836 along the Indian Ocean coast, killing as many as 20 000 people in Zanzibar alone, and almost depopulated the coastal towns of Lamu, Malindi, and Kilwa (1). Thereafter, the trend in cholera cases in Africa appears to have been on the decline; between 1870 and 1970 there were no reported cases of cholera in Africa. Major outbreaks began spreading across the continent in 1970, with epidemics reported in West Africa (Guinea) and the Horn of Africa (Ethiopia, Somalia, and Sudan) and reaching Kenya in 1971 (2). The most severe cholera outbreak on the African continent was in 1998, accounting for more than 72% of the global total number of cholera cases. The countries most severely affected by the 1998 epidemic were the Democratic Republic of Congo, Kenya, Mozambique, Uganda, and the United Republic of Tanzania (3).

As early as the late 19th century, cholera outbreaks were associated with heavy rains. Christie (4) observed that most cholera epidemics along the East African coast started during the monsoons. More recently, cholera epidemics in coastal areas have been attributed partly to the seasonality of sea surface temperatures, which are related to the rainfall (5), warm temperatures and salinity changes related to freshwater influx in coastal marine waters (6), and disease levels prior to an epidemic (7, 8). *Vibrio cholerae* prefers to attach itself to chitinaceous zooplankton and shellfish. Zooplankton and shellfish increase in numbers, following large bursts of phytoplankton associated with warm sea surface temperatures (9). A recent study in Lake Victoria basin (10) noted that the specific social risk factors for cholera in the region include drinking water from the lake or a stream, sharing food with a person with watery diarrhea, and attending funeral feasts. In addition, cholera was more common among those living in villages bordering the lake than among those who lived in the hinterland (10).

The vulnerability of a community or its capacity to adapt to a health risk is determined by the local climatic environment, socioeconomic status, efficacy of governance and civil institutions, quality of public health infrastructure, and access to relevant local information on extreme weather events and disease (11). Studies in which *V. cholerae* are related spatially and temporally to El Niño, or its proxies and predictors, may be an effective way to prevent exposure to cholera (12). Understanding which demographic or geographical subpopulations may be most vulnerable is necessary to reduce potentially adverse health effects driven by climate variability and change (13).

This paper seeks to establish whether there is a relationship between reported and documented cholera outbreaks and climate variability and change. In assessing the vulnerability and adaptability of communities in the Lake Victoria basin to cholera epidemics, country studies were carried out in three selected sites of Kisumu (Kenya), Kampala (Uganda), and Biharamulo (Tanzania) (Fig. 1). These sites are situated in areas that have experienced relatively frequent outbreaks of cholera that are more often related to floods than to poor hygiene. Efforts were made to ensure that communities living at various distances from the lakeshore (0 to 20 km) were included in the study sample. Other factors considered in the selection of sites were proximity to a meteorological station and to a hospital(s) with reliable data. The paper identifies the vulnerable communities and explores the coping mechanisms and critical climate thresholds related to cholera.

METHODOLOGY

Climate Data

Temperature and precipitation data were collected from the Kenya Meteorological Department Headquarters and the Drought Monitoring Center in Nairobi, Kenya, for the period 1960 to 2002. Daily minimum and maximum temperatures (Tmin and Tmax) and daily precipitation values were available for the Kenya site (1978–2002) from four meteorological stations (Kadenge Yala Swamp, Bunyala Irrigation Scheme, Kakamega Forest Station, and Kaimosi Tea Estate Ltd.) located in the Yala catchment of Lake Victoria basin and two meteorological stations (Kisumu Meteorological Station and Kisumu New Prison) located in Kisumu (Nyando catchment of Lake Victoria basin). Monthly Tmin and Tmax and monthly precipitation data were available for Tanzania from 1960 to 2000 and Uganda from 1962 to 2002. The meteorological stations for Uganda and Tanzania were chosen as proxies for the study sites because there were no nearby stations in Tanzania and the dataset for Kampala (i.e., study site) was incomplete.

Due to lack of highly correlated nearby stations, daily temperature data from the Kenya sites were treated according

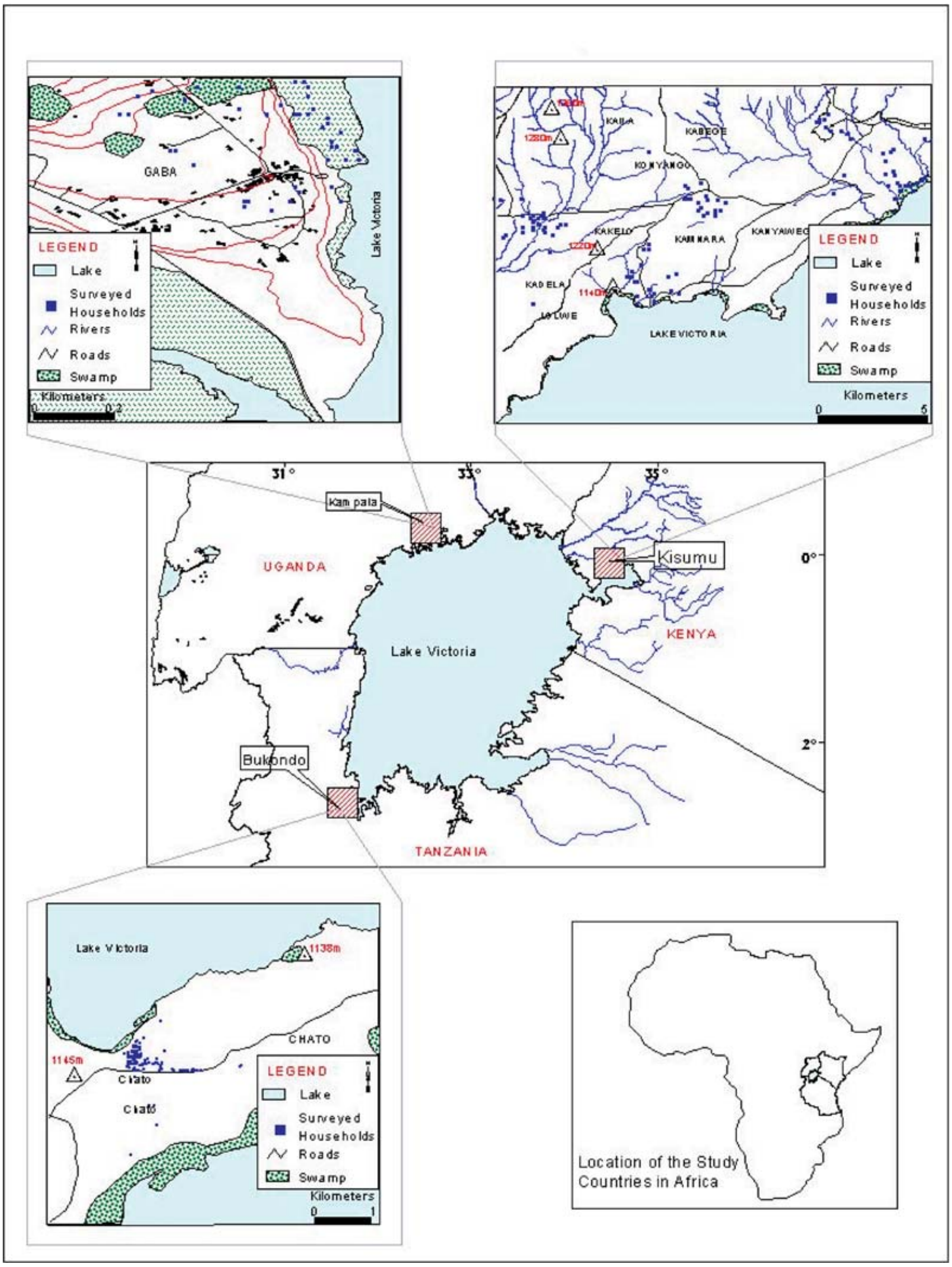

Figure 1. Location of the study sites in the Lake Victoria basin.

to Kemp et al. (14) and were aggregated to monthly values. Monthly temperature and precipitation data from Uganda and Tanzania were filled using the same method. Missing monthly precipitation data were filled using linear regression with the most highly correlated neighboring station (15).

The period 1978 to 1999 was selected to study the relationship between climate, hydrology, and cholera outbreaks because all related stations and cholera case data in this temporal range have continuous time series. Trend analysis (both linear regression and LOWESS [locally weighted scatterplot smooth]) for Tmax and Tmin was performed from the annual averages. LOWESS is a nonparametric technique, in which multiple weighted least squares regressions are performed, until the residuals between the observed data and smoothed data are minimized (16). Kendall's tau-b correlations were performed on the residuals *versus* time to determine the significance of the smooth. The slopes of the regression were tested at the 95% significance level.

Hydrology

In Kenya, the closest gauged rivers to the Kisumu site are the Yala and Sondu Rivers, the Yala being about 20 km from the site. The Yala River (hydrological stations 1FG01 and 1FG02) was chosen because of its contiguous proximity to Kisumu (17) and is therefore used as a proxy for the Kisumu site. Streamflow data were lacking for the Tanzania and Uganda site, because the streams, where present, were not gauged. Data gaps in hydrological data from the Kenya site were filled as follows: data gaps of 7 d or less by linear interpolation and for periods exceeding 7 d by the MOVE 1 technique (Maintenance of Variance Extension type 1) (18).

Socioeconomic and Health Data

An integrated approach using both quantitative and qualitative techniques was employed in assessing the vulnerability and adaptability of the lake basin communities to cholera epidemics. A household survey of 450 semistructured interviews and 11 focus group discussions were conducted at three cholera sites (Kisumu, Kampala, and Biharamulo) in Kenya, Uganda, and Tanzania, respectively. These primary data were complemented with key informant interviews and participatory stakeholder meetings. The survey sample was stratified to ensure that communities living at various distances from the lake (0–20 km) were included in the study.

Thereafter, the households in each of these strata were further stratified by gender, age, and socioeconomic status. The survey sought to establish the health, demographic, and socioeconomic characteristics of the affected communities. The key issues identified by the household survey regarding vulnerability and adaptability to cholera were probed in greater depth in the focus group discussions. The main source of secondary health data in this study was obtained from the Weekly Epidemiological Review (19) and local hospitals with reliable patients' health records. The quantitative and qualitative datasets were analyzed to establish socioeconomic profiles that determine the communities' propensity to either adapt or become vulnerable to cholera epidemics.

CLIMATE OF THE LAKE VICTORIA BASIN

Climatic patterns over the Lake Victoria basin largely reflect that of the eastern Africa region as a whole, with two wet and relatively warm seasons in March, April, and May (MAM) and October, November, and December (OND), and two dry seasons in January and February (JF) (hot and dry) and June, July, and August (JJA) (cold and dry). Within some parts of the Lake Victoria basin, there is a third subdued rainfall peak in August. The largest portion of the interannual variability in rainfall is accounted for by the short rains season of OND (20). Rainfall in eastern Africa is strongly quasi-periodic, with a dominant timescale of variability of 5 to 6 y that is particularly influenced by El Niño Southern Oscillation–induced changes in the short rains period (ON) (20–22)

There has been an increasing trend in Tmax and Tmin for the Kisumu and Kampala sites, but the converse is true for Mwanza, where there has been a declining trend (Fig. 2, Table 1). The Tmax increases from 1978 to 1999 by about 0.6°C for Kisumu and Entebbe but remains constant for Mwanza (Fig. 2). The Tmin likewise shows an increase of about 0.6°C for Kisumu and Entebbe but registers a decrease of slightly higher than 2.0°C for Mwanza (Fig. 2). The LOWESS smooths show that the linear trendlines fitted to the data are reasonable data fits, not unduly influenced by outliers, and suggest that the observed trends and the extent to which they reflect change are fairly robust. All the trends are significant at the 95% confidence level. On the other hand, precipitation increases slightly for Kisumu and Mwanza, but there is a slight decline for Entebbe.

The reasons for the cooling in Mwanza area are unclear but are in part related to the migration of the intertropical convergence zone and southern hemispheric and lake influences. For example, a rainfall analysis for the eastern Africa region during the period 1931 to 1985 (20) shows that Mwanza, Kisumu, and Kampala areas experience more or less similar amounts of rainfall in MA and ND (the rainy seasons), and for the rest of the months Mwanza tends to be significantly drier than Kisumu and Kampala. Of the three rainfall stations, Entebbe receives the highest rainfall and Mwanza the lowest. Although there appears to be no change in the mean annual precipitation received over Kisumu and Entebbe, Mwanza has experienced a slight increase in rainfall for the period 1978 to 1999 (Table 1).

The highest streamflows (Yala River) coincide with the Uhuru Rains of 1961 to 1963, as well as the El Niño years (1968, 1977–1978, 1988, 1993, and 1998). These high flows are at least one standard deviation higher than the mean flows (mean 29.68 m^3 s^{-1} for Yala River station 1FG01 and 32.54 m^3 s^{-1} for station 1FG02). These mean flows generally obscure important, high-flow events, particularly in the short rains season (SOND). For example, some of the maximum monthly flows in the record occur during the month of November. The peak river streamflow lags the rainfall peak (Kisumu station) in April by one month but is coincident with the rainfall peak in November.

The 5-y moving average outlines a decadal cycle in streamflow (Fig. 3), and this is supported by cross-spectral analysis of Yala River streamflow and Kisumu rainfall that reveals a dominant 5-y cycle that likely reflects El Niño Southern Oscillation influences and a 2.5-y cycle that probably represents the influence of the Quasi-Biennial Oscillation. Flood analysis for Yala River (station 1FG01) shows that the 2-, 5-, and 10-y flood events occurred in the short rains season during the 1983, 1992, and 1997 El Niño's. This is consistent with the association of El Niño and the short rains season (20).

Regional Signals of Linkages Between Climate and Cholera

Comparison of the time series plots of the percentage of monthly flow relative to mean annual flow in rivers of the Lake Victoria basin (Kenya) versus the World Health Organization record for cholera outbreaks in the East African region reveals some interesting correlations (Fig. 4a,b). Going by the hypothesis that El Niño-related cholera outbreaks are regional (*versus* those related to hygiene, which are localized and sporadic) and will match the most important months in the year that have the climatological characteristics to precipitate a cholera outbreak, we should be able to detect this effect despite the underlying noise coming from other regions. These plots (Fig. 4a,b) indicate that cholera epidemics (high disease prevalence in all parts of eastern Africa) appear to be closely associated with the El Niño, which is mainly associated with the short rains season (SOND) in eastern Africa. Cholera peaks coincide with high flow peaks during El Niño years in the months of September (1982, 1992), October (1992), November (1982, 1992, 1997), and December (1982, 1992, 1997). During other months of the year, the data (streamflow and cholera occurrences) are offset, indicating that there is no correlation between the two, and hence cholera outbreaks during such years can be attributed to nonclimatic causes.

Tmax appears to play a role in the cholera epidemics as well, because during the years that the epidemics occurred (1982–1983 and 1997–1998), temperatures high above normal are recorded in the Lake Victoria basin region (Figs. 2 and 5). It appears that the temperature trigger is a sustained temperature high above normal for 3 mo in the early part of the year (JFM) followed by a gradual cooling in superceding months (Fig. 5). For the 1997 to 1998 El Niño, the months of September and October 1997 were, additionally, exceptionally warm and probably contributed to the resurgence of the cholera epidemic in January 1998 (Fig. 5). The temperature trigger hypothesis is supported by climate data for the periods 1978 and 1988, when precipitation high above normal and widespread flooding were recorded (Fig. 3), but there was no cholera outbreak because the temperatures were relatively cool, being normal or below normal for the JFM period (Fig. 5).

Thus, cholera epidemics are associated with the anomalously warm and wet El Niño years, such as in 1982 and 1997. More locally in the Lake Victoria basin, the cholera epidemics/outbreaks tend to occur anytime in the year from April to December (data from World Health Organization Epidemio-

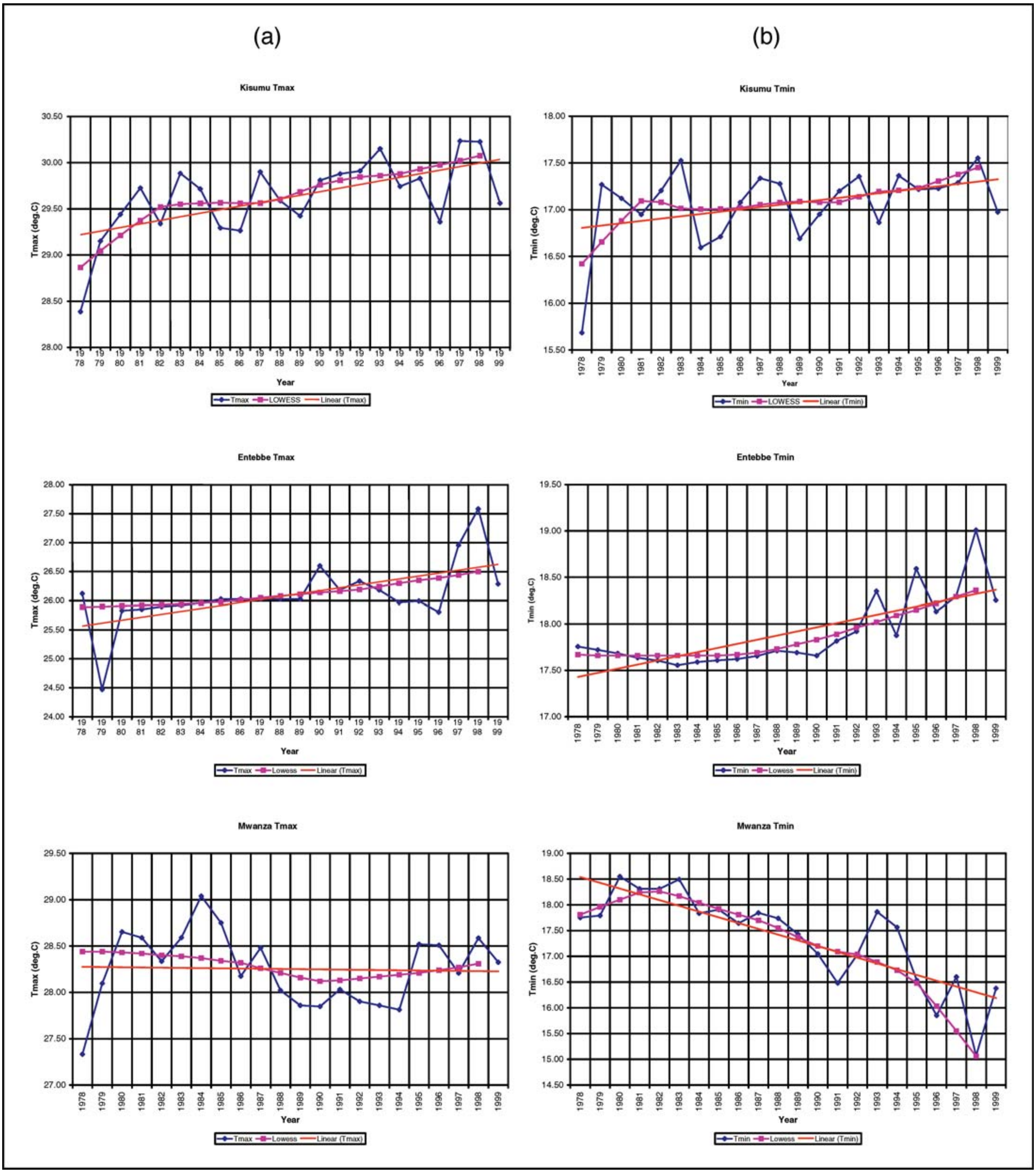

Figure 2. Annual time series of daily maximum and minimum temperatures ([a] Tmax and [b] Tmin) for Kisumu, Entebbe, and Mwanza.

logical Reviews) following periods of mainly sustained anomalous high temperatures in the months of JFM and heavy rains. Therefore, cholera outbreaks (not epidemics) are associated with the long rains season or with the short rains season when there is above-normal rainfall and temperatures but are not as intense as that experienced during El Niño. Abiotic factors (e.g., sunlight, pH, nutrients) that drive aquatic primary productivity also likely play a significant role in enhancing the possibility of cholera outbreaks (12, 23), but this aspect was not assessed in this study.

High-positive anomalies in Tmax are, therefore, required to drive cholera epidemics. In addition, high rainfall and consequent floods are needed to disperse the cholera pathogen in the lake basin area. The climatic thresholds that are required to precipitate a cholera epidemic are therefore as follows: sustained warm monthly temperatures in the months of JFM (exceeding, by at least one standard deviation, the mean annual

Table 1. Summary of trends in climate and streamflow: 1978–1999.

Study site	Direction	α	f
Kisumu			
Tmax	+	< 0.001	0.5
Tmin	+	< 0.001	0.4
Prcp	+	0.04	0.9
Flow	+	0.12	0.3
Mwanza			
Tmax	–	< 0.001	0.9
Tmin	–	< 0.001	0.4
Prcp	+	< 0.001	0.4
Entebbe			
Tmax	+	< 0.001	0.7
Tmin	+	< 0.001	0.9
Prcp	–	0.47	0.9

Tmax = daily maximum temperatures; Tmin = daily minimum temperatures; Prcp = daily precipitation values

temperature for the period 1978 to 2002) coupled with sufficient rainfall to produce at least a 2-y flood event in rivers around the lake during the SOND rainy season. This climatic effect can be exacerbated and prolonged by similarly anomalous temperatures and rainfall in the SOND, with its effects being reflected in the JF hot and dry season. When the above climatic factors are met, human vulnerability to cholera epidemics is dramatically increased.

Socioeconomic and Health Systems

The characteristics of the local environment examined in the preceding sections indicate that intertwined variability of the climatic signals of temperature, precipitation, and streamflow above certain thresholds triggers cholera epidemics in the East African lake basin region. How the communities respond (by either adapting or becoming vulnerable) to these epidemics is in turn determined by their socioeconomic status, effectiveness of governance and civil organizations, quality of public health structures, and the level of awareness of cholera epidemics and their relationship to climate variability and change.

Socioeconomic Status

The socioeconomic characteristics suggest certain poverty indices that reflect the vulnerability of these communities to cholera epidemics. Most of these communities are poor, relying predominantly on either farm incomes or self-employment. Formal employment that is a source of steady income is the privilege of only a few, with 8%, 23.7%, and 12.7% relying on this source of income in Kisumu, Kampala, and Biharamulo, respectively. The income disparities in total monthly incomes are also large, which is symptomatic of inequity in these communities. These vary between 2.3–283 USD; 4.2–1000 USD and 2.1–73 USD in Kisumu, Kampala, and Biharamulo, respectively.

The type of food and frequency of meals that a household has is a good measure of household food security. Although most of the households reported having a fairly well-balanced diet of proteins and carbohydrates, a significant proportion of the households in the study areas indicated days of household food shortages. The highest proportion was reported in Kisumu for 89.3% of the households followed by Uganda and Tanzania at 34.4% and 18.7%, respectively. What happens to the crops grown may also be used to indirectly measure the level of the lake basin communities' involvement in the monetary economy and thereby challenge their ability to afford medical care during cholera epidemics. In Biharamulo and Kisumu only 1.5% and 6.4%, respectively, of the households sell all their agricultural produce, whereas in Kampala it is significantly higher, at 31.4%.

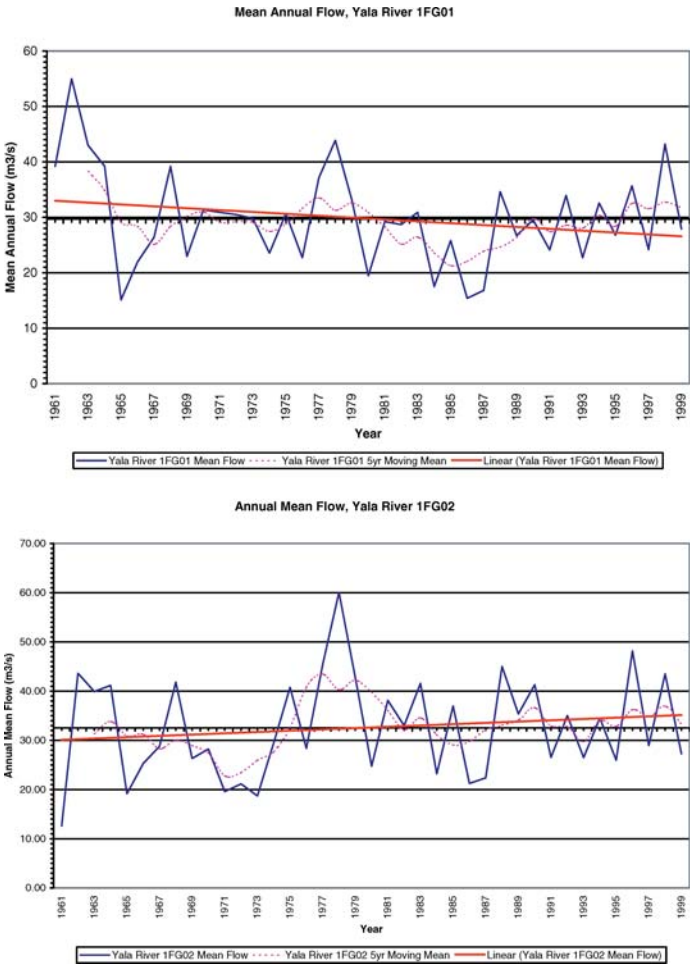

Figure 3. Mean annual flows for Yala River for the period 1961 to 1999.

Most residential houses in the survey areas are semipermanent (iron roofs and mud walls), accounting for 54.7%, 68%, and 63.3% of the respondents' houses in Kisumu, Kampala, and Biharamulo, respectively. Kisumu and Kampala, which are both cities, do not reflect an urban infrastructure (such as a greater density of permanent houses: stone/brick walls and tiled roofs) commensurate with their city status. Coupled with other factors, such as income levels and food insecurity, this is an indication of the low socioeconomic status inherent in these communities.

Governance and Civil Institutions

Disaster management has the goal of saving lives and not leaving people worse off than before the disaster. A key component of this is the institutions, both public and private, that are in place to mitigate the effects of disasters resulting from extremes or variability in climate. With the increasing frequency of cholera outbreaks in the Lake Victoria basin, certain governance structures have evolved, reflecting the different roles played by the local government, nongovernmental organizations (NGOs), and the private sector. Because most of the public health care systems appear to be ill equipped to handle cholera epidemics, the role of the local administration is increasingly narrowing down to creating awareness about the disease. The NGOs, on the other hand, assist the communities in operationalizing the advice received by providing material support. For instance, in Kisumu, several NGOs have been instrumental in assisting the communities to construct wells and pit latrines. In case of an outbreak, these NGOs also provide free medical drugs. With the

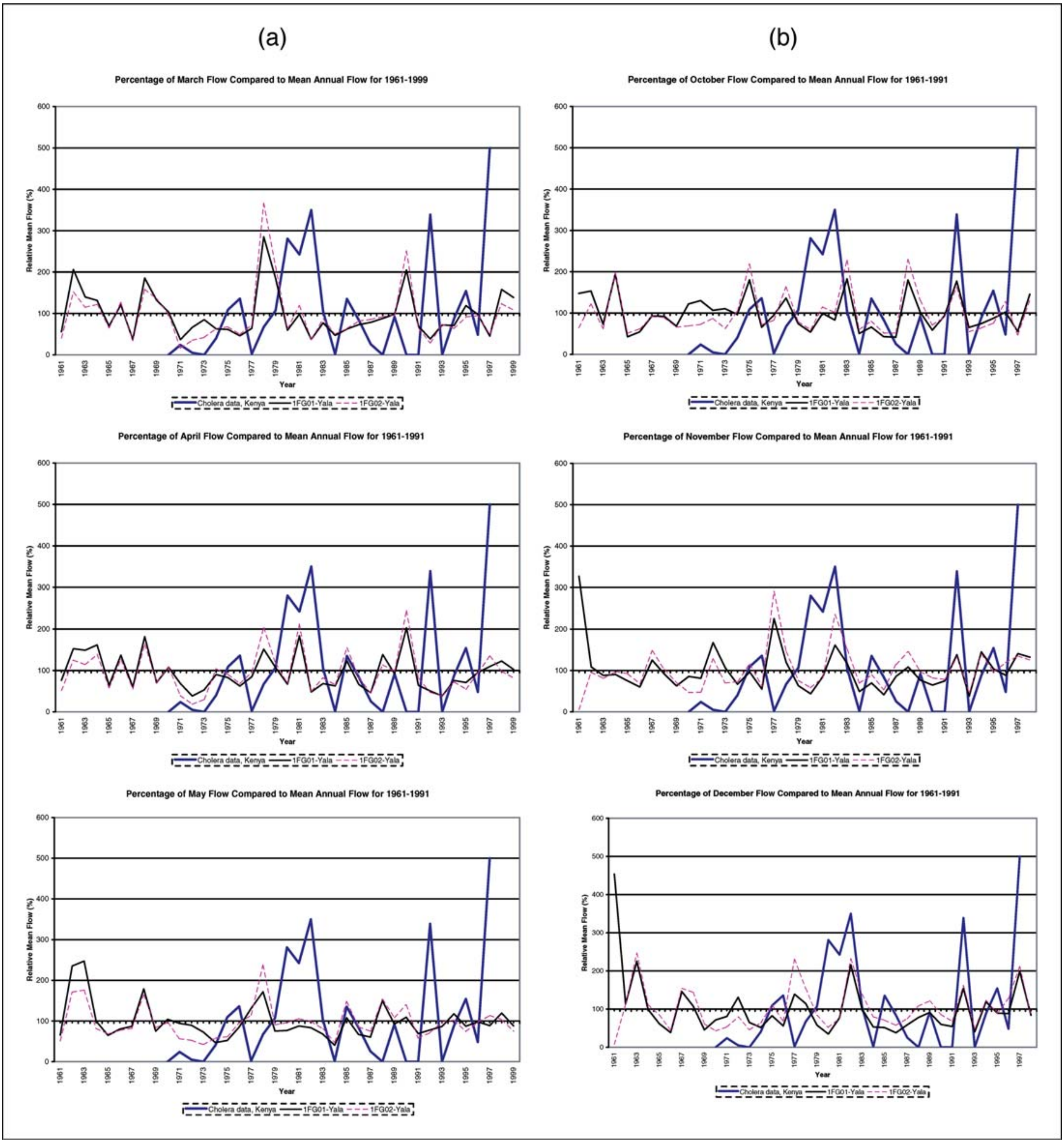

Figure 4. a) Long rains season: Association between cholera epidemics and streamflow in March, April, and May. Note that the high cholera incidences are offset from streamflow peaks, suggesting that there is no relationship. b) Short rains season: Association between cholera epidemics and streamflow in October, November, and December. Note that the high cholera incidences are coincident with streamflow peaks, suggesting that there is a relationship between flooding and cholera during this season.

deterioration of the public health care system, the private sector has increasingly become the only viable option, which is nonetheless limited by the low incomes inherent in these communities. The civil society has taken the lead in boosting the adaptive capacity of these communities (such as through the construction of potable water sources and proper toilet facilities), but they still have not been able to cover most of the areas affected by cholera epidemics. Similarly, in Kampala the local administration has constructed pit latrines for the local communities using funds from the Local Government Development Programme. In order to maintain these facilities, a small fee is paid for using them. However, specific adaptation interventions have yet to be instituted. For instance, anticipatory interventions, such as watershed protection policies and effective early warning systems, are still lacking. Thus, on the whole, disaster management of cholera epidemics particularly by the government has been more reactive than proactive. This has greatly undermined the efficacy of governance and civil institutions to contain cholera epidemics in the East African lake basin. Mitigating against the impacts of cholera epidemics

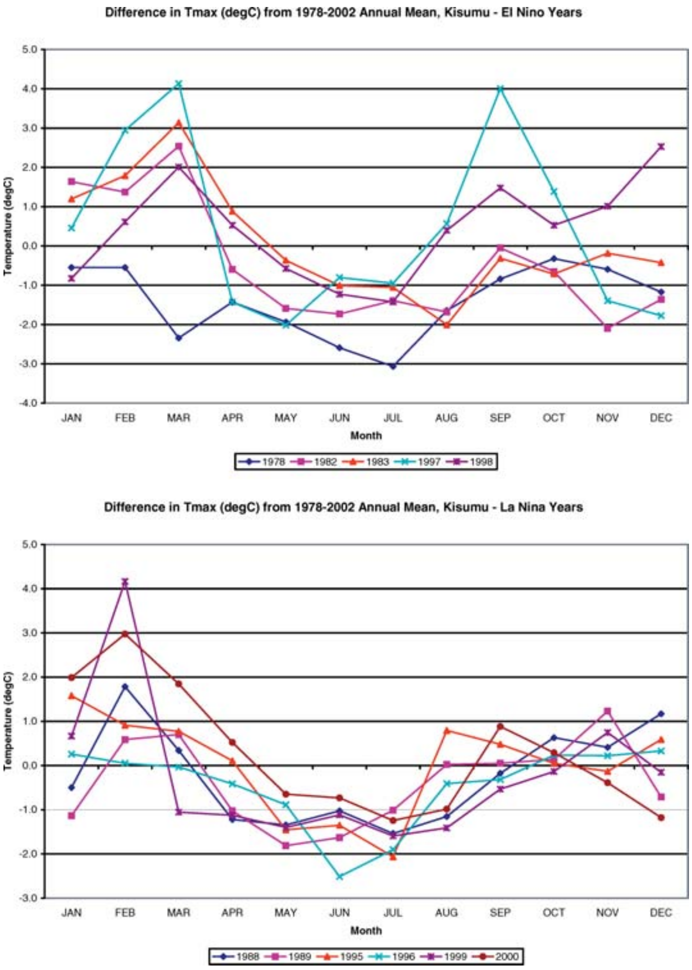

Figure 5. Difference in daily maximum temperatures (Tmax) from the mean for the period 1978 to 2002, Kisumu during El Niño and La Niña years.

necessitates a shift in emphasis from disaster response to risk management, which might include improved flood forecasting, better early warning systems, improved communications, and support for strategies that mitigate risk.

Public Health Infrastructure

Lack of adequate health care systems coupled with persistent poverty greatly compromises the adaptive capacity of individuals and communities to take advantage of opportunities and cope with the consequences of cholera epidemics. Cholera has been one of the most potent forces in bringing about the mobilization of public health resources because an outbreak of cholera places the burden of responsibility on those institutions that have not provided adequate safe water and sewage disposal for the affected communities. However, the poor quality of the public health infrastructure in the East African lake basin indicates low levels of such mobilization. To check the spread of cholera epidemics, certain minimum hygienic standards are required and thus directly related to the source of water and sanitation facilities available in the affected communities. The source of water used in the households can be a health hazard, particularly in terms of water-borne diseases. Nearly four-fifths (80.7%) of the communities rely on drinking water from rivers/streams and the lake (Table 2), which may be contaminated by waste disposals (24), exposing them to the risk of such water-borne diseases as cholera. Although nearly two-thirds (63.8%) of the households boil their drinking water, a significant number (25%) do not treat it at all (Table 3). The cost of fuel

Table 2. Sources of water.

Source	Kisumu (%)	Biharamulo (%)	Kampala (%)
Lake	22.9	49.0	4.4
Protected well	7.6	14.8	3.6
Borehole	11.0	22.2	0.6
Roof catchment	0	7.0	3.2
Tap	19.3	7.0	78
River/stream	31.3		
Unprotected well	3.1		6.7
Spring	2.2		
Pond	2.2		3.6

Table 3. Water treatment methods.

Type of treatment	Kisumu (%)	Kericho (%)	Muleba (%)	Biharamulo (%)
Boiling	63.8	48.0	1.3	53.3
Filtering	6.9	0.7	0.0	50
Chemicals	4.1	2.7	4.0	3.3
None	25	48.7	92.3	12.7

Table 4. Type of toilet facilities.

Type of toilet	Kisumu (%)	Kampala (%)	Biharamulo (%)
Pit latrine	67.3	86.3	97.3
Bush	32.7		
Water closet		13.7	2.7

wood for boiling water was the most common reason why they do not treat their water using this method, again an indicator of the low incomes levels prevalent in the region. Given the reported unhygienic environment and recurrent incidences of cholera in the lake basin, the lack of treatment of drinking water makes the respective households vulnerable to getting cholera.

The sanitation facilities available to the communities indicate that most of the households do not have access to proper toilets and rely predominantly on pit latrines and the bush (Table 4). Pit latrines, if not located and constructed properly, may pollute subsurface water storage or nearby surface water systems, posing a danger to the health of the people. Because a significant proportion of households in the survey rely on the bush as a toilet, these communities' adaptive capacity to cholera epidemics is severely compromised. Lack of or inadequate usage of proper toilet facilities appears to be a common problem around Lake Victoria. In Biharamulo and Kisumu, for example, pit latrines often collapse due to the sandy nature of the soils; the ensuing human waste thus flows freely into the lake. In Kampala, because of the occurrence of a high water table, the probability of lake contamination is significantly increased. When cholera or other infectious diarrheal diseases occur, such people may be highly vulnerable to getting the diseases.

The extent to which communities succumb or are resilient to climate-related stresses is partly affected by the ability of the public health system to respond to and cope with climate-related diseases. The capacity of public health infrastructure (such as clinics/dispensaries and hospitals) to cater to the increased incidence of disease and epidemics is essential. Because the mortality rate of untreated severe cholera can be up to 70%, the need to have adequate health facilities cannot be overemphasized. In Kisumu and Biharamulo, public health facilities are the predominant treatment centers, whereas in Kampala private clinics cater to about two-thirds of the households. Rarely do they visit the provincial hospitals that are better equipped and have in-patient facilities (Table 5). To get to medical health facilities, most people have to walk;

Table 5. Type of health facility visited.

Health facility	Kisumu	Kampala	Biharamulo
Provincial hospital	1.3	8.7	
District hospital	9.3	7.5	
Health center	66.7	0.8	100.0
Local dispensary	20.0	1.6	
Mobile dispensary			
Herbalist		3.3	
Private hospital	0.7	12.6	
Private clinic	2.0	65.4	
Total	**100%**	**100%**	**100%**

Table 6. Visits to health facilities in the last three months by household members.

No. of visits	Kisumu (%)	Kampala (%)	Biharamulo(%)
0	46.7	43.5	28.0
1	22.7	32.0	41.3
2	17.3	16.0	16.0
3	8.7	4.6	9.3
4	3.3	1.5	2.0
5	1.3	0.8	2.0
6		0.8	0.7
11		0.8	
15			0.7
Total	**100%**	**100%**	**100%**

indeed, some of the households are located within walking distances to the nearest dispensary/health center. However, the debilitating nature of cholera prevents the patients from walking to the health facilities, subsequently limiting their access to the public health care systems. The inaccessibility of health facilities is also reflected in the low frequency of visits to the health facilities (Table 6). Coping mechanisms that increase the accessibility of the local health infrastructure need to be developed to boost the adaptability of the affected communities.

Information

Public perception and awareness of extreme weather events and disease are among the critical factors determining the prevention and adaptive capacity of individuals and communities to the impact(s) of such climate-sensitive diseases as cholera. Generally, a significant proportion of the respondents (86.6%, 67.2%, and 52.7% in Kisumu, Kampala, and Biharamulo, respectively) tend to think that the health of household members is associated with weather conditions. Based on experiential rather than scientific underpinnings, the respondents indicate that cholera occurs mostly during wet weather conditions and during periods of low water supply associated with dry seasons. The explanation provided by health workers from Biharamulo was that it is because of the sandy nature of the soil that pit latrines often collapse during rainy season. Similarly, awareness of the causes and prevention of cholera is equally high. Most households are knowledgeable about the necessary medical treatment, such as the use of antibiotics and oral rehydration salts. However, they indicated that they rarely used such medical treatment because of the costs involved and instead rely on those that are distributed during such epidemics.

Coping Mechanisms and Adaptation Measures

The poverty indicators outlined in the preceding sections undermine the coping mechanisms that could help the susceptible East African lake basin communities reduce their vulnerability to cholera epidemics. This is because of lack of economic resources to invest in health coping mechanisms that can offset the costs of adaptation. Measures employed at the household level include washing hands before meals, treating drinking water, and constructing pit latrines. The communities were also able to distinguish between the different levels of responsibility in the control of cholera (Table 7). The strategies at the village level do not require as much economic resources as those at the district level, a reflection of the communities' awareness of this limitation.

CONCLUSION

Cholera outbreaks and epidemics can be linked to natural, socioeconomic, and health systems. The climate and hydrological data show that the onset of cholera within the Lake Victoria basin starts earliest in the month of April within any given year following a sustained 3-mo period of Tmax and Tmin (JFM), in combination with above-normal rains and flooding from April through December. There may be some epidemics in January that are related to sustained Tmax in SOND season, as occurred

Table 7. Cholera control strategies.

	Village level	District level
1.	Construction and use of improved toilets	Awareness campaigns on how to prevent cholera outbreaks
2.	Use of clean and safe water (boiled)	Outbreak preparedness (districts need to have plans for controlling cholera in the event of outbreaks)
3.	Use of clean and safe water (boiling cooking and drinking water)	Outbreak preparedness
4.	Proper collection and disposal of wastes Collecting solid wastes in pits and burying the pit when they fill up Burning the wastes, when possible	Planning for cholera control strategies in cooperation with community leaders Provision of equipment necessary to keep the environment clean and improve the hygienic conditions
5.	Protection and proper management of water sources	Recruitment of more health staff
6.	Cost sharing in the management of water sources	
7.	Washing hands before taking any food/meals	Undertaking of environmental assessment to ascertain causes of problems and how to control the situation
8.	Washing fruits before eating	
9.	Washing hands after visiting toilets	
10.	Cleanliness of household utensils	Establishment of temporary camps for patients during cholera outbreaks
11.	Community to report promptly when there is a cholera outbreak	Prompt response to cholera outbreak
12.	Sick people to report promptly at health centers and hospitals for treatment	Undertaking of laboratory analysis to confirm outbreak

during the El Niño of 1997 to 1998. The analyses of climate and hydrological data indicates that the threshold for the outbreak of cholera cases is one standard deviation above mean Tmax for a period of 3 mo (JFM) in any given year, associated with superseding high streamflow and floods in subsequent months.

An assessment of the vulnerability and adaptability of these lake basin communities indicates that poverty plays a very big role in the vulnerability of the communities to climate variability and change and variations in the socioeconomic and health systems. Due to poverty and inadequate, or lack of, early warning mechanisms, the communities lack effective strategies for coping with climate-induced shocks, such as disease and weather extremes. Shortage of food resulting from frequent droughts and floods contributes to malnutrition, particularly in the poor households, resulting in ill health that makes individuals easily succumb to such diseases as cholera. At the same time, lack of access to potable water and good sanitation facilities makes these communities more vulnerable to cholera epidemics. It is these poor families who cannot afford preventive and curative measures who have high cholera mortality rates. The East African riparian communities living along the lake shore are more vulnerable to cholera epidemics due to climate variability and change and poverty. The ability of these communities to cope is strongly challenged by these factors. Because the effect and intensity of the disease is very closely associated with poverty, its eradication is essentially linked to poverty alleviation.

Future adaptation programs should take into account the diversity of factors that influence a society's capacity to cope with the changes. Such programs should take into consideration the demographic trends and socioeconomic factors. Similarly, the public health infrastructure and the institutions of governance need to be improved. Climate variability and change no doubt play an important role in the people's health and productivity and their responsiveness to extreme weather events. The management of cholera outbreaks and epidemics must factor in climate considerations if it is to reduce vulnerability and increase the adaptive capacity of the lake basin communities.

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24. Apart from being a source of food, energy, drinking, and irrigation, the waters of Lake Victoria are also a repository for human, agricultural, and industrial waste.

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