THE DIVERSITY & ECOLOGY OF THE EAST AFRICAN LAKES, WITH A CASE STUDY OF LAKES BARINGO, NAKURU AND VICTORIA-NYANZA

By:

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Outline of Presentation

1: Introduction

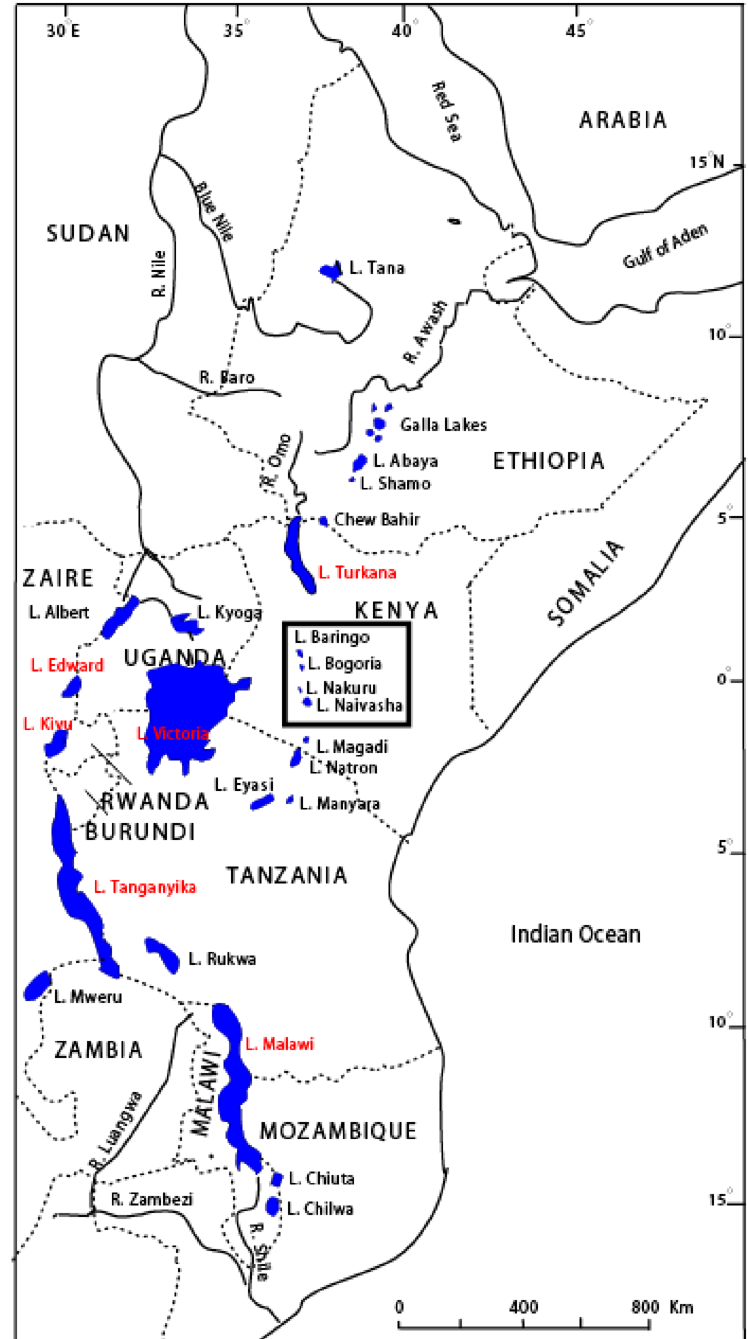
2: Sensitivity of the Lakes

3: Threats and Issues - overview

4: Conclusion

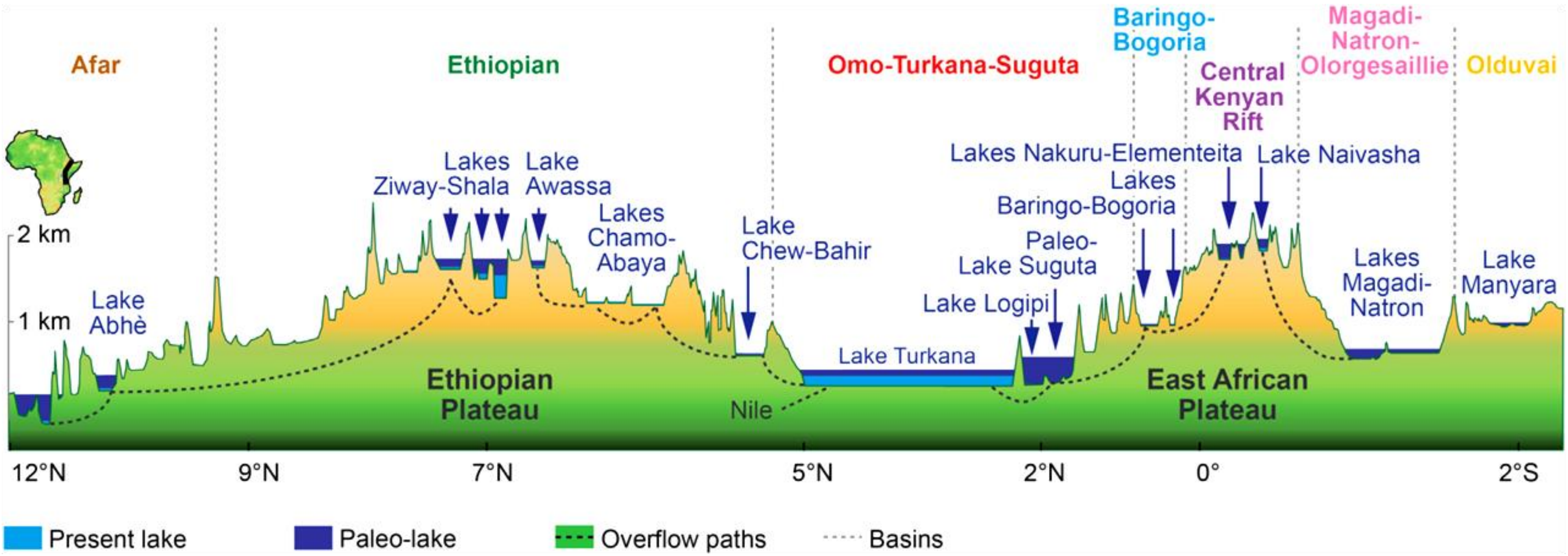
Introduction

- Lakes Baringo and Nakuru lie in Kenya Rift Valley (130,452 km^2) - topographically closed area draining into Lake Turkana in the north and Lake Natron to the south
- Initiation of the two oldest deep rift basins of the Central Kenya Rift, the Kerio Basin and the Baringo Basin formed in Paleocene time (>38 Ma)
- Present-day lakes Baringo, Nakuru, Elementaita and Naivasha are the remnants of largest lake domains developed during Lower-Middle Pleistocene times (ca. <780,000 yr ago)
- Lake Victoria formed by uplift along western branch of EARS in late Pleistocene (ca. 400,000 yr ago), and back-ponding of rivers that previously drained westwards



From: Olago et al., 2009

(adapted from Nyamweru C.K., 1983)



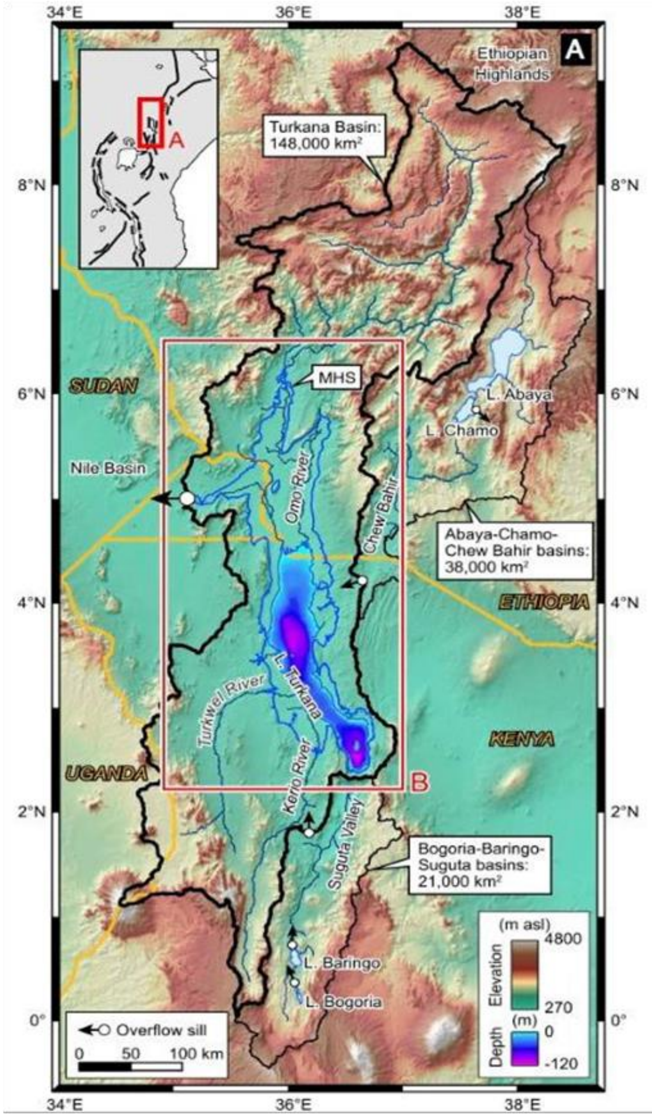
Afar
Ethiopian
Omo-Turkana-Suguta
Baringo-Bogoria
Central Kenyan Rift
Magadi-Natron-Olorgesaillie
Olduvai
Lakes Ziway-Shala
Lake Awassa
Lakes Chamo-Abaya
Lake Chew-Bahir
Lakes Nakuru-Elementeita
Lake Naivasha
Lakes Baringo-Bogoria
Paleo-Lake Suguta
Lake Logipi
Lakes Magadi-Natron
Lake Manyara
2 km
1 km
Lake Abhè
Ethiopian Plateau
Nile
Lake Turkana
East African Plateau
12°N
9°N
7°N
5°N
2°N
0°
2°S
Present lake
Paleo-lake
Overflow paths
Basins

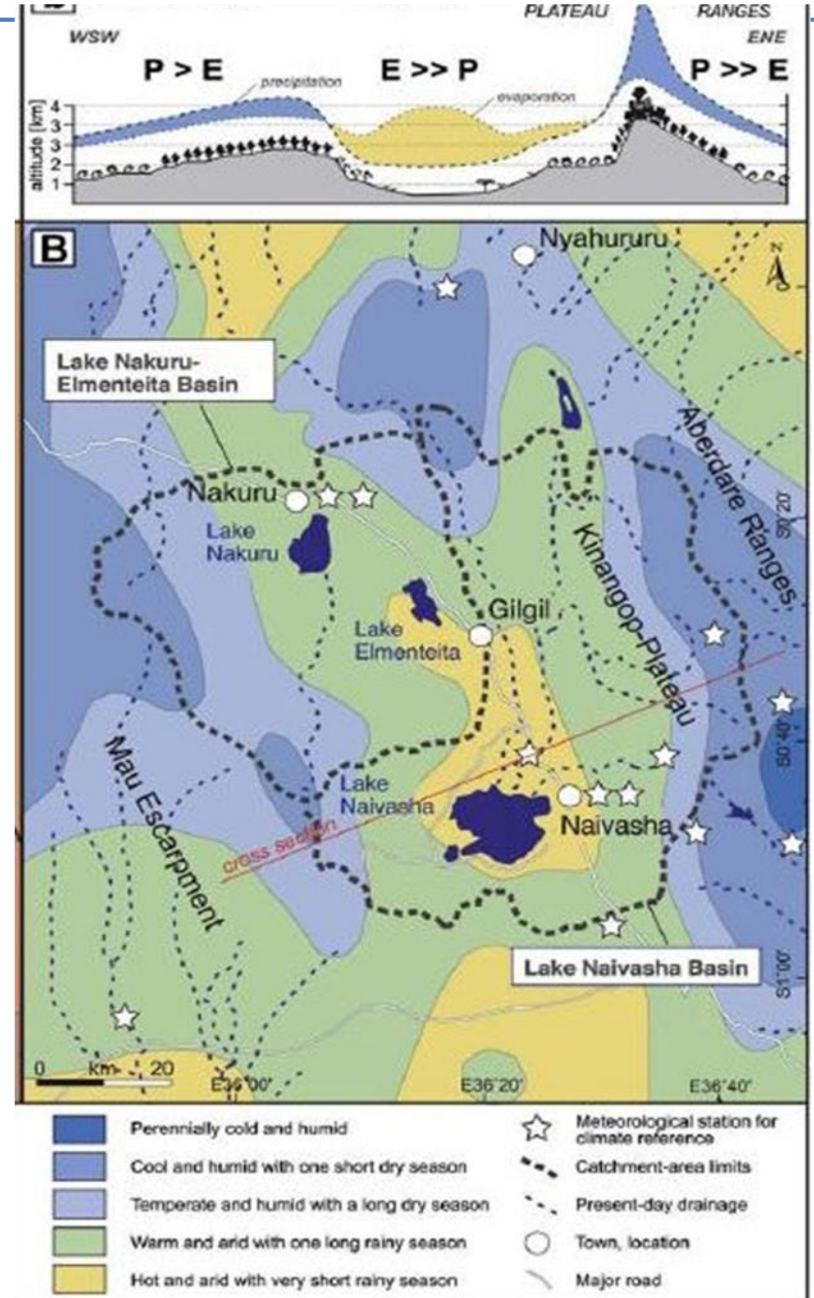
Introduction - 2

- The lakes in the Kenya Rift are generally small (maximum 30 x 20 km), shallow (from 5- to 50-m water depth), and, with exception of Naivasha & Baringo, have more or less saline characteristics, mainly because they lie in areas under semi-arid climatic conditions and/or have no outlet

Lake basin	Altitude (m)	Basin area (km^2)	Lake area (km^2)	pH	Depth (m)	Land use	Population density (km^{-2})
Naivasha	1890	2378	160	7.68–8.75	Max: 11.5 Mean: 6.5	Town, irrigated farmland	98
Elmenteita	1776	590	20	9.00–10.00	Max: 1.2 Mean: 0.9	Ranching	96
Nakuru	1759	1760	45	10.49	Max: 2.8 Mean: 2.3	Town, farmland	115 (rural) to 974 (town)
Bogoria	960	1110	34	10.30–10.70	Max: 10.0 Mean: 5.4	Pastoralism	72
Baringo	975	6820	160	8.97–9.15	Max: 9 Mean: 5.6	Pastoralism	72
Lake Victoria	1134	~184000	68800	7.30-8.50	Max: 84	Farmland, towns	250
Lake Victoria Kenya	1134	38913	4100	7.30-8.50	<55	Farmland, towns	174-224

The smaller lakes are climate-sensitive "Amplifier" lakes - are relatively small with large catchments, in a semi-arid climate





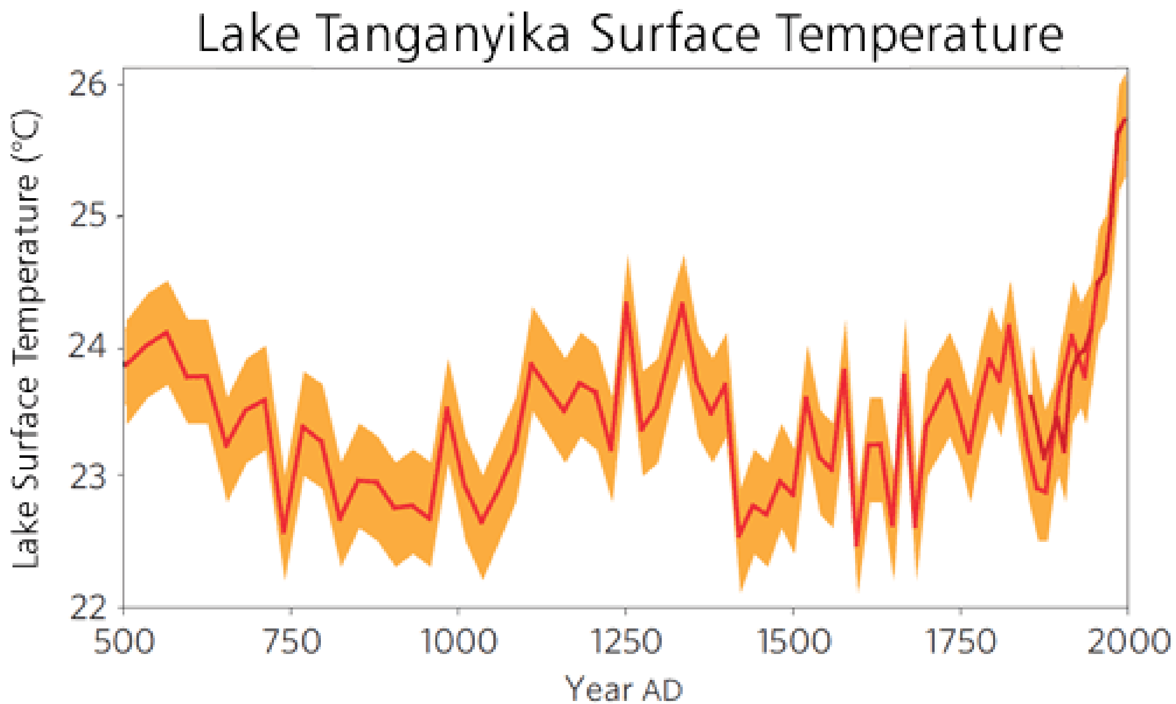
Garcin et al. (2012) *EPSL*
Bergner A. et al. (2009) *Quat. Sci. Rev*.

Issues – Climate Change and Lakes

- The major effects of climate change on African water systems will be through changes in the hydrological cycle, the balance of temperature, and rainfall
- Changes in hydrological cycle and circulation leading to stratification e.g. in Lake Turkana, stratification influenced the distribution of fish in the deep water over as much as 20% of the lake area (Kallqvist et al. 1988).
- Stratification restricts vertical mixing and enhances temperature gradients between the surface and bottom waters, hence lower oxygen exchange and impeded nutrient exchange.
- Lake level changes may expose/submerge littoral communities, and volume changes may result in changes in water physico-chemical properties, leading to changes in habitat for aquatic species
- Reducing precipitation and higher temperatures can result in increased concentrations of pollution in a lake due to reducing lake level (and volume).

Issues – Climate Change and Lakes (cont'd)

- Warming has been observed in the recent decades in air and water temperatures of tropical lakes
- It was discovered that local temperature rises, less windy conditions and climate change have dramatically altered the nutrient balance of Lake Tanganyika (O'Reilly et al. 2003, Verburg et al. 2003), cutting off fish production.

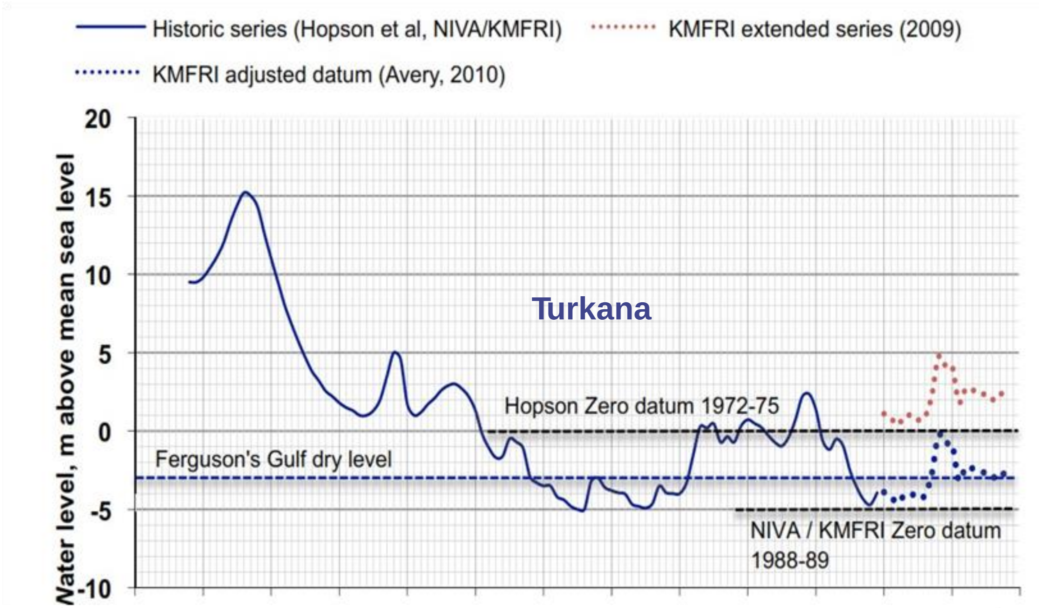


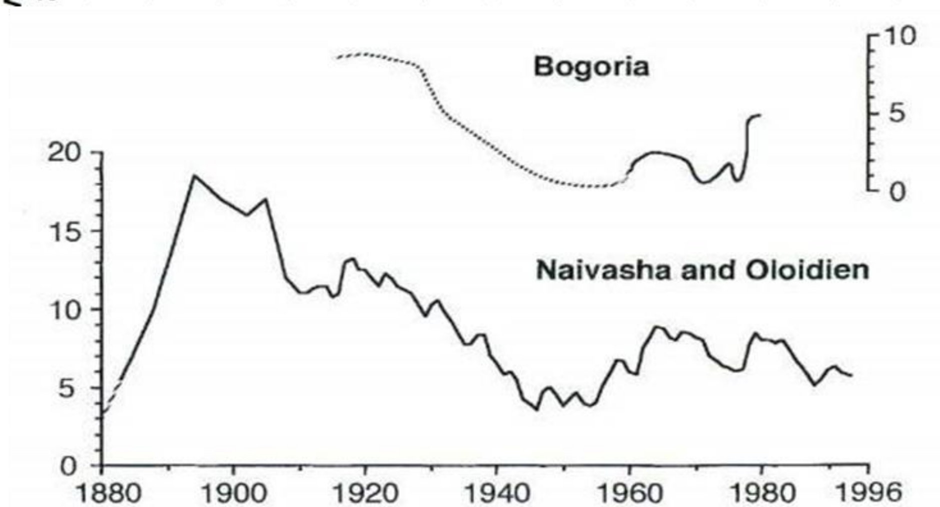
Lake Surface Temperature from Lake Tanganyika palaeorecord for the past 1,500 years, measured in core KH1 (red line) and MC1 (dark red line) with 95% error bars (orange shading). (Tierney et al., 2010)

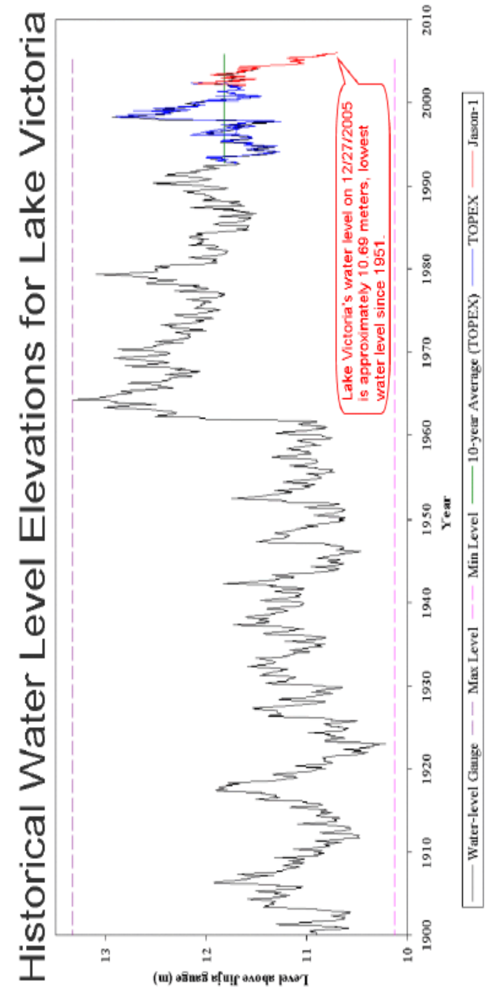
Example: Lake Victoria and Climate Change

- Lake Victoria is sensitive to climate change as its water balance is dominated by rainfall on the lake and evaporation, with river inflow and outflow making minor contributions (UNEP 2004).
- Global warming will lead to higher temperatures estimated to be between 0.2 and 0.5 ºC per decade for Africa (Hulme and others 2001).
- Lake Victoria was one half of a degree (°C) warmer in the 1990s than in the 1960s (Hecky and others 1994; Bugenyi and Magumba 1996).
- Maximum temperatures in the region have been progressively increasing over the past two to three decades.
- It is also likely that extreme events such as El Niño are being experienced more frequently, and have become more intense (IPCC 2001) in the basin.
- The 1997 El Niño which saw Lake Victoria level rise by 2.4m (Birkett and others 1999) was the strongest in the region and caused wide-ranging agricultural, hydrological, ecological, economic and health impacts (Conway 2002).

Long-term lake-level fluctuation: the last century







Avery (2012) *Report African Studies Center, Oxford*
Tiercelin et al. (1987) *Bull. Centr. Rech. Expl.-Prod. Elf-Aquitaine*
Åse et al. (1986) *Forsk. Naturgeogr. Inst. Stockholm Univ*

Climate Change Projections

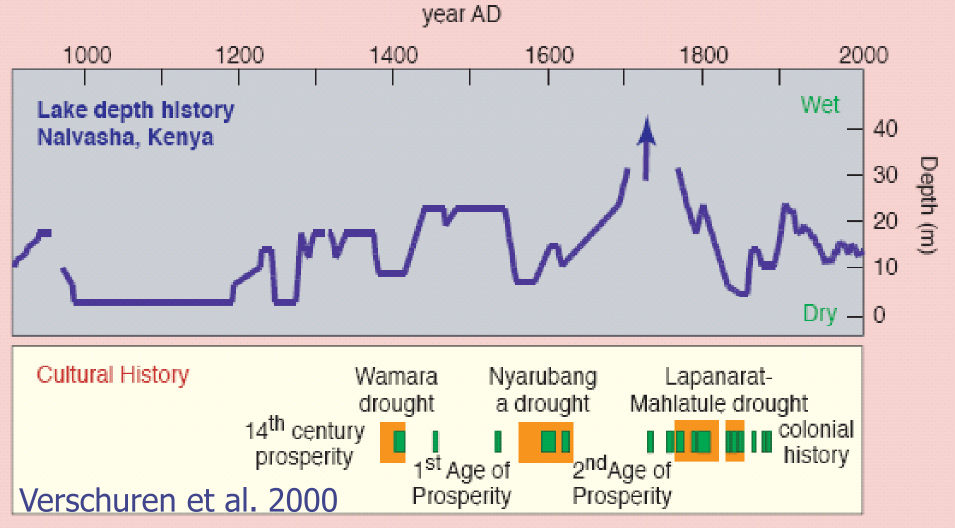
- climate change will alter the timing, distribution and quantity of water resources across the region (Goulden et al. 2009).
- Climate models show a consistent response in both mean annual and seasonal temperature change in the region, projecting warmer conditions of +3.2°C for East Africa by the 2080s.
- There is consistency amongst models in projecting wetter conditions in East Africa, by +7% (from Goulden *et al.* 2009).
- Wetter conditions, flooding and flood frequency flood risk to the region is exacerbated by land degradation and erosion
- Dry conditions, droughts and water scarcity

Hydrological Perspectives from Long-term Data

- Apparently small changes in precipitation if persistent, can result in large hydrological responses, affecting environment and human civilisations – CLIMATE SURPRISES

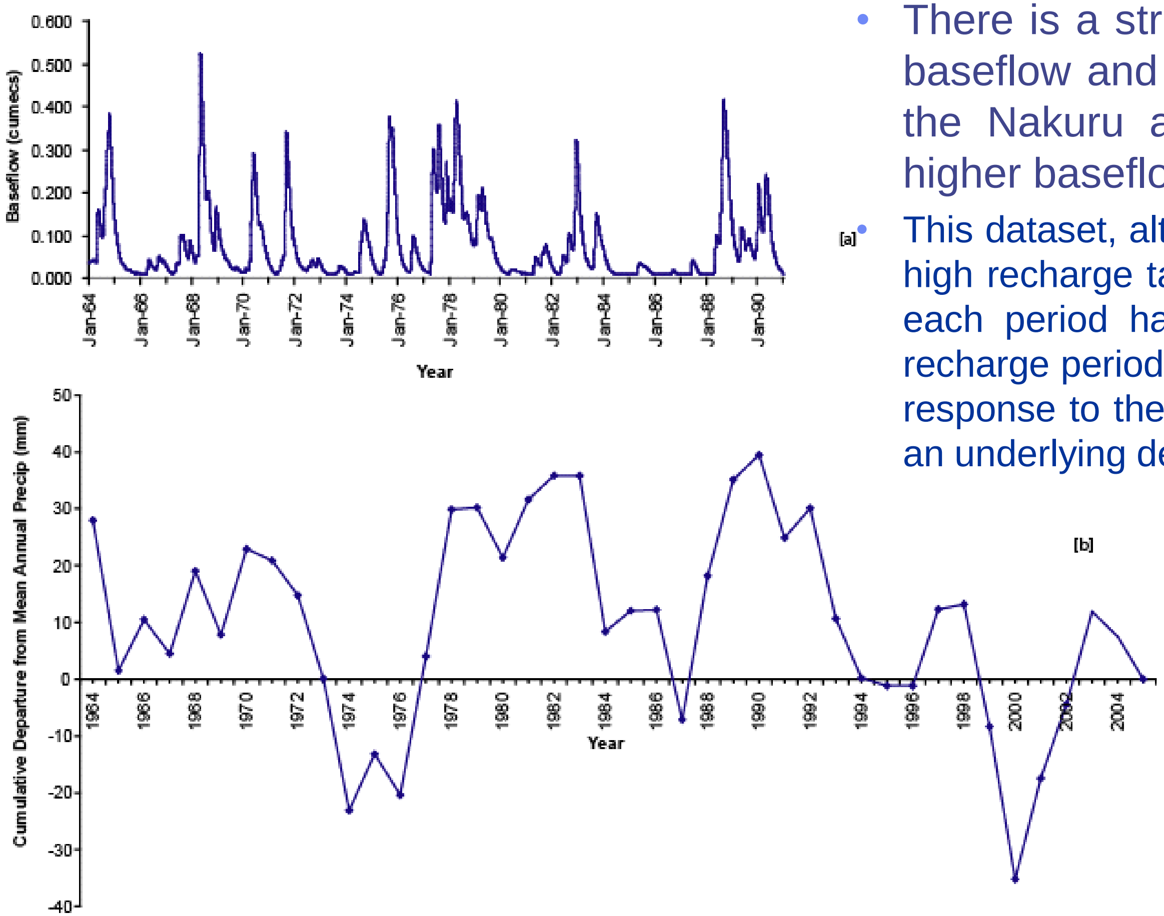
Odada and Olago, 2005

Area	Time period (yr BP)	Rainfall mm/yr	Rainfall %	Source
Ziway–Shala basin, Ethiopia (7° to 8° 30′ N)	9,400 to 8,000		+25	Street, 1979; Gillespie *et al.*, 1983
Turkana basin	10,000 to 7,000	+80 to +140	+10 to +19	Hastenrath and Kutzbach, 1983
Lake Turkana, Kenya	10,000 to 4,000	+200	+27	Vincens, 1989b
Nakuru–Elmenteita basin	10,000 to 8,000	+260 to +300	+29 to +33	Hastenrath and Kutzbach, 1983
Naivasha basin	9,200 to 5,650	+90 to +155	+10 to +17	Hastenrath and Kutzbach, 1983
Victoria basin	AD 1880	+170 to +220	+14 to +18	Hastenrath and Kutzbach, 1983
Lake Naivasha	AD 1890s	+150		Vincent *et al.*, 1989



Verschuren et al. 2000

Groundwater Recharge to Lakes



(a) Baseflow timeseries for Njoro River. (b) Cumulative rainfall departure for Nakuru rainfall station (An upward slope indicates a wet period and a downward slope indicates a dry period).

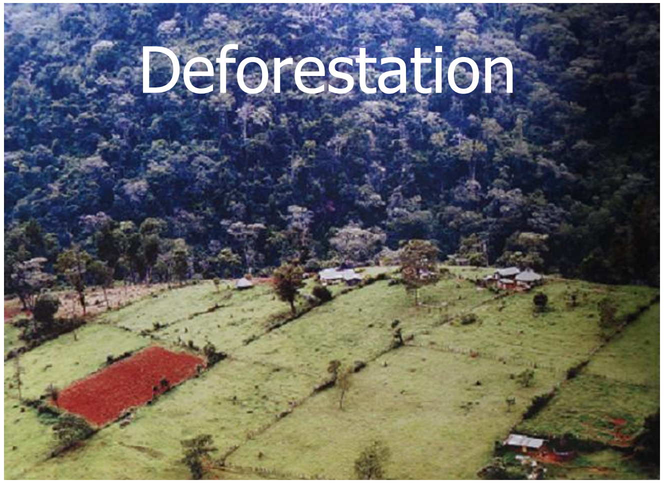
- There is a strong positive correlation between baseflow and cumulative rainfall departure for the Nakuru area: wet periods coincide with higher baseflow and vice versa for dry periods
- This dataset, although limited, suggests that effective high recharge takes place every ten years or so and each period has a duration of 3 years, while low recharge periods last between 6 to 10 years, either in response to the interannual variability of ENSO or to an underlying decadal scale drying cycle.

- This may explain the observation by Becht and Nyaoro (2005) that Lake Naivasha water level and groundwater levels take decades to stablise and equilibrate following over-abstraction.

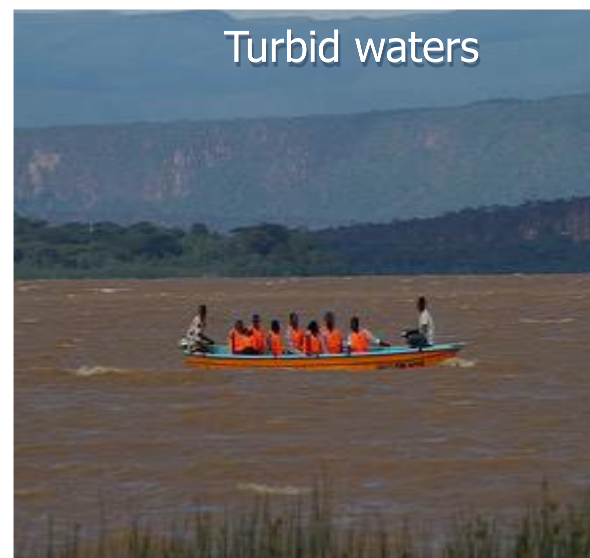
Vulnerability of Freshwater and Super Saline Ecosystems to Climate Change

- Climate related changes could lead to:
  - species loss,
  - changes in the ecosystem structure and function, and
  - ecosystem collapse.
- Due to their low species diversity, the Naivasha and Albert lake systems lack the possible buffering effect of species redundancy that could offer resilience to both climatic and human-induced disturbances (cf. Martens, 2002).
- Aquatic ecosystem changes in e.g. tropical lakes suggest that equilibrium species (those that characterized the river/lake systems, are stable over decades or centuries, and tend to be species-rich) will have to give way to opportunistic species types (which tend to have poorer diversity) due to the continual instability of the water regime.

Threats to Lake Baringo, Fresh water



- The Baringo area has long been recognized as an example of human misuse and mismanagement of land resources.
- Governmental officials identified the area as one of the worst-eroded areas in Kenya in the 1930s. In 1963 L. H. Brown described the situation as tragic (Thom and Martin, 1983)
- Gully, sheet, and rill erosion occurs in varied degrees

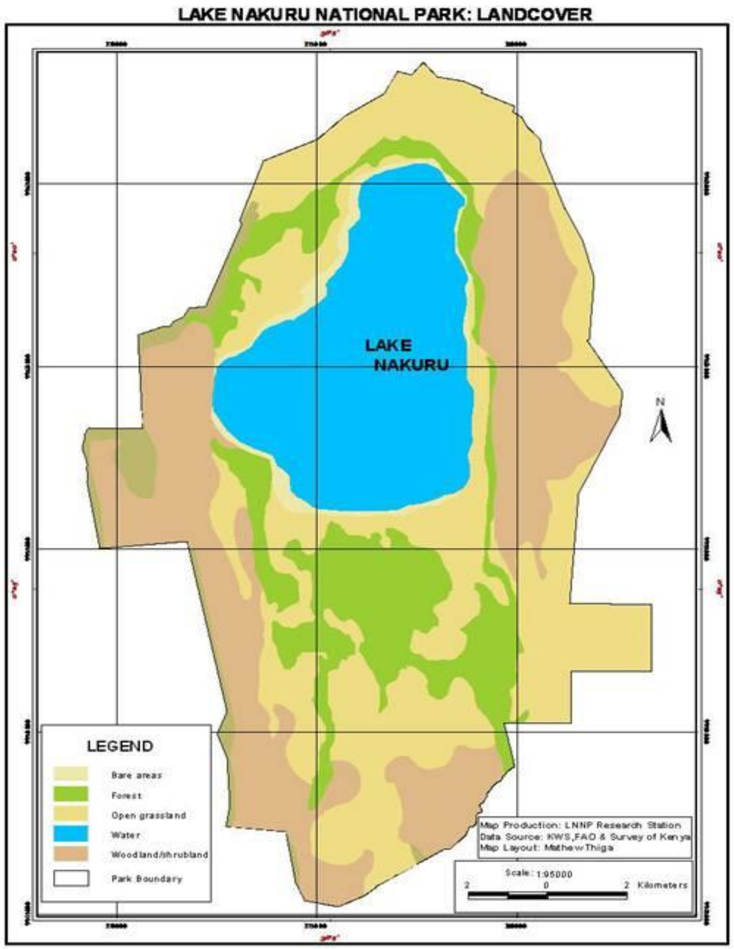


Issues in Lake Baringo

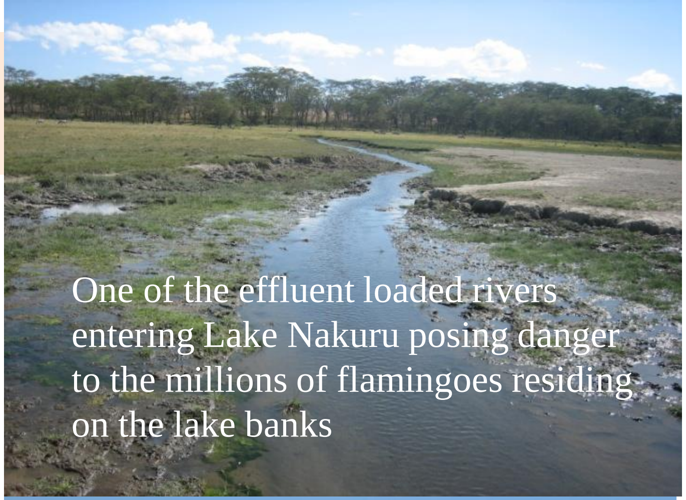
Environmental	Land degradation, Turbidity & high sedimentation in lake, Nutrient loading, Alkalinity
Ecological	Biodiversity loss, Habitat degradation, Land cover changes, Algal blooms
Ecosystem Goods and Services	Decline in fish catch and biomass, aesthetics
Economic	Decline in tourism income and fish revenue, livelihoods affected
Social	Tourism income and fish revenue declines, Livelihoods affected, Land/water related conflicts
Governance	No ILBM system in place

Lake Nakuru, Kenya: Super Saline Ecosystem

Threats to Lake Nakuru



- UNESCO World Heritage Site (2011)
- Threats are focused to the town area north of the lake



Issues in Lake Nakuru

Environmental	Pollution (runoff and sewage), steep hydrological fluctuations
Ecological	Changing food web structure due to hydrological changes, affects food chain
Ecosystem Goods and Services	Park & tourism
Economic	Tourism affected by lake level changes and Pollution from sewage/runoff
Social	Expanding settlements, water demand for multiple uses threaten influent surface/groundwater supply
Governance	No ILBM system in place

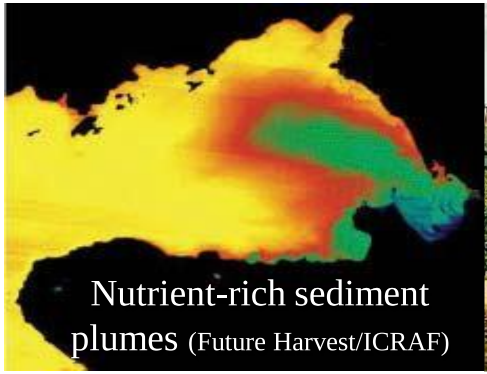
Threats to Lake Victoria-Nyanza

Algal bloom in Lake (J. Okungu)

Sand harvesting, R. Awach (Kwast 2002)

Overdependence on wetland vegetation

Wanton destruction of trees



Nutrient-rich sediment plumes (Future Harvest/ICRAF)

Water hyacinth blocks Kisumu Ferry Terminal (http:edcintl.cr.usgs.gov/waterhyacinth.html)

- In 1940-60 the Lake Victoria water was clear and filled with life. Today it is murky, smelly and choking with algae.
- The water quality deterioration partly related to poor municipal wastewater treatment systems and poor land-based practices (UNEP, 2005).
- Loss of fish biodiversity related in part to species introductions (e.g. nile perch vs. decline in haplochromines) but nile perch fishery is $$$$$!

Issues in Lake Victoria-Nyanza

Environmental	Land degradation, Pollution (runoff/sewage), High sedimentation, Introduced/Invasive species
Ecological	Changing food web structure, Eutrophia - species Extinction/invasion, Anoxia, Warming lake waters
Ecosystem Goods and Services	Unsustainable use of wetland resources; reduced Livelihoods options
Economic	Overfishing & pollution related to fisheries decline, Poverty-environment trap, reduced land values
Social	Expanding settlements, displacements, conflict, loss of fish foods
Governance	Several regional organisations/projects; poor coordination & inclusion at grassroots level

The Monitoring Focus
Common Needs ≡ Sustainable Lake Basins

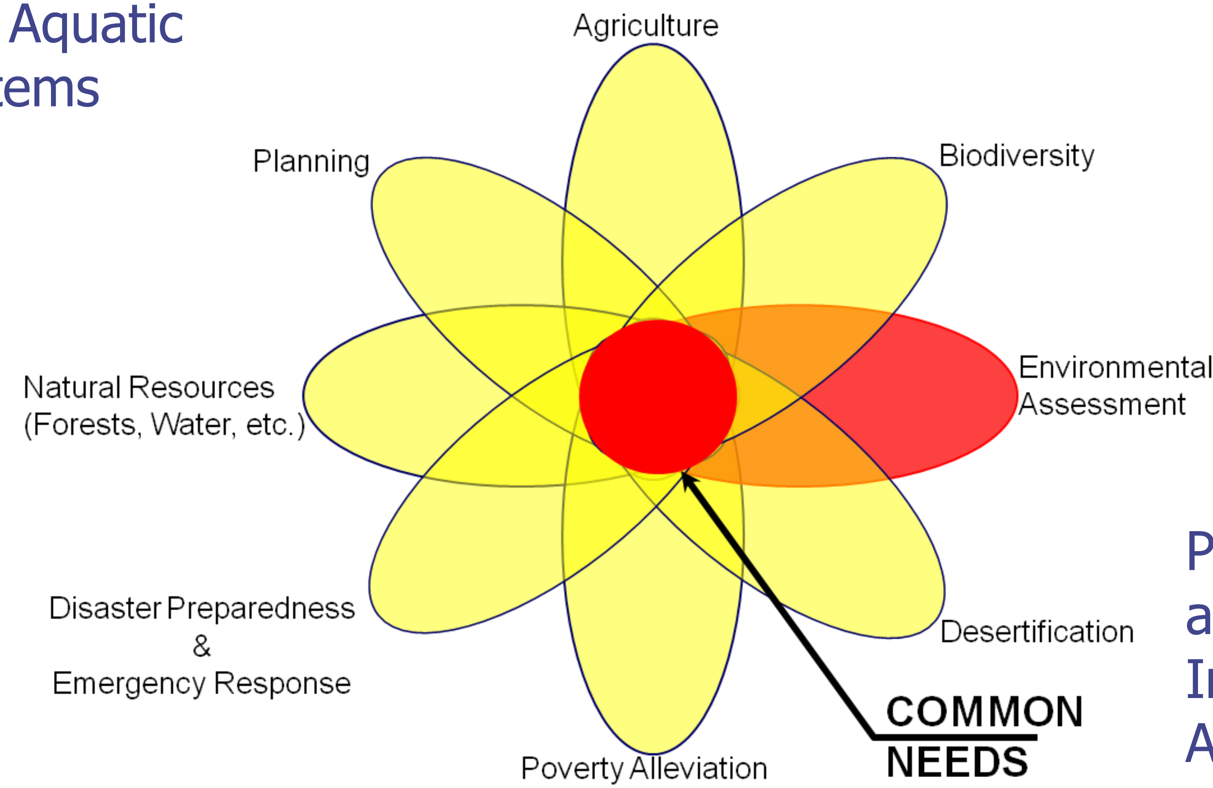
Domains of overlapping needs

⇨ **Coincidence of opportunities**

⇨ **Synergy, lower "project" costs**

⇨ **Opportunities for cost-sharing**

Terrestrial and Aquatic Systems



Participatory and Interative Approaches

Conclusions

- Lakes are highly sensitive to climatic/hydrological changes and anthropogenic activities – changes can affect revenue streams from e.g. tourism, agriculture/aquaculture, horticulture
- Human activities in catchments and on lakes threaten aquatic ecosystems e.g. pollution, sedimentation, species introductions.
- Relationships between human activity and the physical environment are complex and any productive activity can deplete natural resources and cause environmental stress.
- On the other hand, environmental problems can prevent people from reaching an acceptable standard of living - particularly true for poor people.
- The problems facing each of the basins are multi-faceted, similar in drivers but varying only in the relative importance of the drivers
- To understand and solve the problems requires many different insights and contributions encompassing historical factors/decisions through to cultural, ecological, socio-economic, governance and other aspects
- Long-term view (transgenerational) is important (slow lake response time, large natural effects on long timescales, uncertainties due to climate change)