AQUATIC HABITATS IN AFRICA

Gamal M. El-Shabrawy
National Institute of Oceanography and Fisheries, Fish Research Station, El-Kanater El-Khayriya, Cairo, Egypt

Khalid A. Al-Ghanim
College of Sciences and Humanity Studies, P. O. Box- 83, Salman bin Abdul-Aziz University, Alkharj 11942, Kingdom of Saudi Arabia

Keywords: Human impacts, water utilization, African lakes, rivers, lagoons, wetlands

Contents

Summary

Although, Africa has abundant freshwater resources, 14 countries are subject to water stress (1700 m^3 or less per person per year) or water scarcity (1000 m^3 or less per person per year), and another 11 countries are expected to join this list in the 2025. This chapter highlights the major aquatic habitats in Africa, including the main rivers, lakes, lagoons and wetlands. The economic importance and human interaction with the water of these aquatic habitats are discussed. A combination of climatic changes, human population growth, unsustainable resource use, and desertification is threatening the African ecosystems and ability to supply crucially needed natural resources to the people of Africa. Unfortunately, the human pressure on African aquatic ecosystems is expected to increase as populations grow, unless strategic action plans are put in place for their conservation. National and international efforts are required to manage these habitats.

1. Introduction

Although the presences of large rivers and lakes such as the Congo, the Nile, the Zambezi, the Niger, Lake Victoria (the world's second largest), Lake Chad, Lake Tanganyika, etc., Africa is the second driest continent in the world, after Australia, and millions of Africans still suffer from water shortages throughout the year. Shortages are often due to problems of uneven distribution (sometimes there is much water where there are fewer people) and also to management of existing supplies that could be improved (WWF, 2002).

Aquatic habitats are defined as water bodies supporting aquatic life. They include: rivers, streams, lakes, ponds, cave water, springs, floodplains, and wetlands (bogs, marshes, and swamps) that provide water for drinking, sanitation, agriculture, transport, electricity generation and recreation (CBD 2005). They provide valuable but often unaccounted for, regulation of floods, drought, nutrient and sediment deposition. They are also habitats for diverse faunas and floras which constitute a vital and important source of food and fiber that sustains incomes and livelihoods, particularly for rural communities in all developing countries (CBD, 2005).

Africa is the second-largest continent after Asia and is currently considered among the most strategic regions in terms of global development opportunities. The vast landscape of Africa contains a host of natural wonders and rich resources. Its grasslands, wetlands, mountains, deserts, rainforests and marine areas are home to thousands of species of plants and animals. Africa is rich in freshwater systems comprising natural lakes, man-made lakes or reservoirs and rivers.

The major lakes (Fig. 1) include in alphabetical order Albert, Bangwuelu, Chad, Chilwa, Edward, George, Kivu, Kyoga, Malawi (Nyasa), Mweru, Nasser-Nubia, Tanganyika, Turkana, and Victoria. The major man-made lakes include: Cahora Bassa (*Also spelt Cabora Bassa.*), Kariba, Kainji, Nasser-Nubia and Volta. The larger natural lakes of the rift valley include Albert, Edward, George, Kivu, Tanganyika and Turkana. In addition, the rift valley has a number of smaller lakes including Baringo, Bagotia, Nakuru, Naivasha, Magadi, Natron, and Manyara (Ogutu-Ohwayo and Balirwa 2006). The African Great Lakes include Victoria which is the second largest lake in the world,

Lake Tanganyika which is the second deepest lake in the world. Other smaller lakes such George, Nakuru, Naivasha have been useful in understanding the production processes in African lakes. The African lakes such as those of the Rift valley are amongst the oldest on earth (e.g. Lake Tanganyika: 2-20 million years BP) and are sensitive to climatic and physico-chemical changes. Lake Victoria is reported to have dried up about 12,500 years ago (Johnson et al, 1996) while 6000 years ago Lake Chad was 20 times larger and its maximum depth was 154 m compared with about 4 m today (ILEC, 2003). As recent as the 1960s, the environments (particularly water level) of Lakes Victoria, Kyoga, Tanganyika and Malawi have changed in response to variable rains. The African lakes contribute significantly to poverty reduction and food security. They are a source of dietary proteins and water, they provide revenue through fish harvest, export and tourism, and are used as avenues for transport of people and goods. The lakes also provide water for irrigation, agriculture and hydropower projects. Lakes Malawi, Tanganyika and Victoria harbour diverse endemic fish faunas of ecological and scientific importance.

During this century, African lakes have experienced declines in fish catches, reduction in fish species diversity and deterioration in water quality. Much effort has already been put in mitigating these threats but there is still need to strengthen these efforts.

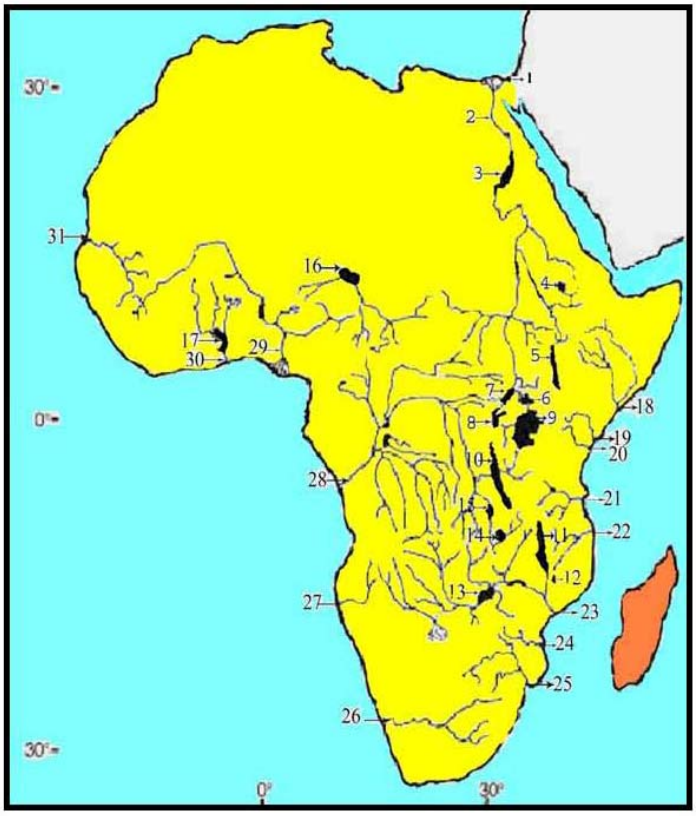

Figure 1. The main rivers and lakes in Africa (Modified from Ogutu-Ohwayo& Balirwa, 2006)

Lakes : 1 - Bardawil lagoon; 3 - Nasser-Nubia; 4- Tana; 5 - Turkana; 6 - Kioga; 7 - Albert; 8 - Edward; 9 -Victoria; 10 - Tanganyika ; 11 - Malawi ; 12 – Chilwa; 13 - Kariba; 14 - Bangwelu ; 15 - Mweru ; 16 - Chad; 17 - Volta
Rivers : 2 - Nile ; 18 - Juba-Schebele ; 19 - Tana ; 20 - Athi ; 21 - Ruaha ; 22 - Ruvuma ; 23 - Zambezi; 24 - Save (Sabi-Lundi) ; 25 - Limpopo ; 26 - Orange; 27 - Kunene; 28 - Zaire; 29 - Niger; 30 -Volta; 31 - Senegal.

2. African Aquatic Habitats

Aquatic ecosystems consist of living organisms together with their nonliving habitat. Although the ecosystem concept is a useful one, the exact definition is somewhat arbitrary. For example, an ecosystem can range in size from a small water droplet to the vast oceanic ecosystem, and the upper, lower, and horizontal boundaries are often not well established. Similarly, the temporal aspects of ecosystems are often fuzzy. For example, a vernal (spring) pond is a temporary wetland filled with rainwater, and is transformed from an aquatic ecosystem into a terrestrial one when it dries up during the summer. An intermittent stream is one that sometimes is full of water and at other times dry. Ecosystems are not always self-sustaining. For example, fish and other aquatic animals in streams depend on leaves and insects falling from terrestrial (land) ecosystems as energy sources. Just as no single life form (species) is sufficient unto itself, neither is any one ecosystem. Ecosystems and their plant and animal life are not independent from one another in time, space, or energy. The four basic parts of any ecosystem, whether aquatic or terrestrial, are: • abiotic (nonliving) substances (mainly inorganic and organic compounds), producers (largely green plants), • consumers (animals), and decomposers (bacteria and fungi). Plants, animals, decomposers, and organics are interdependent with one another.

Any large geographic region characterized by a certain type of ecosystem is known as a Biome. Aquatic biomes may be freshwater (lakes, ponds, rivers and streams), Freshwater/brackish (estuaries and wetlands) and marine (inter-tidal regions, coral reefs, oceanic pelagic zones and abyssal zones). An ecosystem is generally defined as a community of organisms living in a particular environment and the physical elements in that environment with which they interact. Within each ecosystem, there are habitats which may also vary in size. A habitat is the place where a population lives. A population is a group of living organisms of the same kind living in the same place at the same time. All of the populations interact and form a community. The community of living things interacts with the non-living world around it (soil, water, air and energy), to form the ecosystem. The habitat must supply the needs of organisms, such as food, water, temperature, oxygen, and minerals. If the population's needs are not met, it will either die off or move to a better habitat. The processes of competition, predation, parasitism, cooperation, and symbiosis occur and characterize habitats.

Inland aquatic habitats, such as rivers, lakes, ponds and wetlands, provide a range of important ecosystem services and benefits to society. However, the unsustainable use of aquatic habitats, including by the urban water management sector itself, tends to alter and reduce their biodiversity and thus their ability to provide services, including clean water, protection of human health from waterborne diseases and pollutants, protection of urban areas from flooding, and the maintenance of aesthetic and recreational

ecosystem services. Spurred by increasing urbanization, population increases and climate change, this is a global issue that is likely to grow more and more serious over the coming years, in particular in the South. If it is not addressed, there is the threat that several of the Millennium Development Goals will not be reachable (Wagner et al, 2007).

Country	No. of lakes	Percentage
Uganda	69	10.0
Kenya	64	9.5
Cameroon	59	8.7
Tanzania	49	7.2
Ethiopia	46	6.8
South Africa	37	5.5
Rwanda	29	4.3
Ghana	29	4.3
Morocco	26	3.8
Madagascar	25	3.7
Egypt	16	2.4
Nigeria	16	2.4
Mali	15	2.2
Tunisia	15	2.2
Zaire	15	2.2
Malawi	13	1.9
Botswana	12	1.8
Gabon	8	1.2
Others	134	20.0
Total	**677**	**100**

Table 1. Principal lakes in Africa

2.1. Lakes

Lakes are usually formed when natural depressions or basins in the land surface become filled with water over time. They can range from small ponds to water-bodies stretching hundreds of kilometers and containing vast quantities of water. In contrast to flowing streams and rivers, lakes provide a means for pooling or storing water for varying periods of time. They provide water for consumption, fishing, irrigation, power generation, transportation, recreation, and a variety of other domestic, agricultural and industrial uses (Zinabu 1998).

Africa, particularly East Africa, has numerous lakes that support important fisheries which provide livelihoods for millions of people and contribute significantly to the food supply (UNEP 2006). According to the world lake database, there are 677 lakes in Africa, with 88 of them listed as principal lakes (Table 1). Although lakes are a source of livelihoods in most African societies, they are also a major source of natural disasters, tropical diseases and pandemics. It is important to note that Africa's lakes are also undergoing significant changes due to a combination of human activities and

climate change, with potentially serious implications for people's livelihoods and aquatic biodiversity. The major characteristics of main rivers of Africa are shown in Table (2).

	Volume	Surface area	Shoreline Length	Mean Depth	Max depth	Residence time	Country
	km^3	km^2	km	m	m	Year	
Tanganyika	**18900**	**32900**	**1900**	**750**	**1435**	**440**	**Burundi, Congo, Tanzania, Zambia**
Malawi	**8400**	**30900**	**245**	**290**	**706**	**114**	**Malawi, Mozambique, Tanzania**
Victoria	**2750**	**69000**	**3440**	**40**	**92**	**21**	**Kenya, Tanzania, Uganda**
Kivu	**569**	**2370**	**-**	**240**	**496**	**400**	**Congo, Rwanda**
Albert	**280**	**5300**	**-**	**3**	**58**	**-**	**Congo, Uganda**
Edward	**78.2**	**2325**	**-**	**17**	**112**	**-**	**Congo, Uganda**
Chad	**72**	**1600**	**650**	**4**	**8**	**-**	**Cameroon, Chad, Niger, Nigeria**
Tana	**28**	**3150**	**385**	**9**	**14**	**1.5**	**Ethiopia**
Volta	**148**	**8500**	**4800**	**19**	**75**	**4.3**	**Ghana**
Kariba	**185**	**5580**	**2164**	**30**	**97**	**3**	**Zambia, Zimbabwe**
Chilwa	**1.8**	**1750**	**200**	**1**	**2.7**	**-**	**Malawi, Mozambique**
Nasser_Nubia	**162**	**6000**	**7844**	**26**	**120**	**-**	**Egypt, Sudan**
Turkana	**204**	**6750**	**-**	**30**	**109**	**12.6**	**Kenya**

Table 2. Major characteristics of main lakes of Africa

2.1.1. Lake Tanganyika

Lake Tanganyika (03° 30' and 08° 50' S and 29° 05' and 31° 15' E) is an ancient lake with a history of geographical isolation of some 20 million years. It occupies a deep and narrow trough of the western branch of the Rift Valley of East Africa (Coulter, 1994). Lake Tanganyika is the largest and oldest of the Rift Valley lakes and the second largest and deepest freshwater body in the world after Lake Baikal (Horne and Goldman, 1994). The lake is ca. 650 km long and 50 km in average wide with an approximate surface area of 32,600 km^2 and volume of 18,880 km^3. Lake Tanganyika is shared by four nations, *viz.*, Burundi, Tanzania, Democratic Republic of Congo and Zambia. Flora and fauna therefore have unique characteristics not found elsewhere (Coulter, 1991). There are three distinct basins: the Kigoma basin in the north (max depth: 1310 m), the Kungwe basin in the centre (max depth: 885 m) and the Kipili basin in the south (max depth: 1410 m). Lake Tanganyika is meromictic with anoxic monimolimnion. It has the second largest volume of anoxic water in the world after the Black Sea. While the large volume of Lake Tanganyika provides a temporary buffer against a deterioration in the water quality (Spigel and Coulter, 1996), the long residence time creates conditions in

which human generated pollutants can accumulate, leading to negative effects on the lake's water quality, fish stocks and biodiversity (Verschuren, 2003).

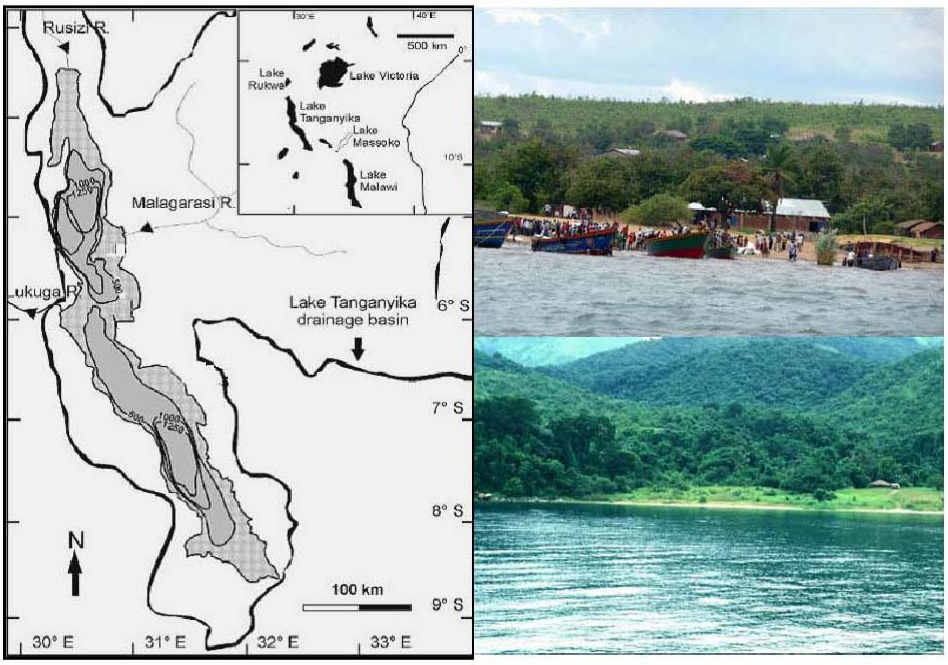

Figure 2. Lake Tanganyika basin After Allison et al., (2010)

-
-
-

Bibliography

References

Aboul-Ezz S. M. (1988). Periodicity and distribution of bottom fauna in the hypersaline Bardawil lagoon. Bulletin of the National Institute of Oceanography and Fisheries of Egypt 14(1): 159 – 174. [This paper illustrates the standing crop and community composition of the lake bottom fauna].

Ali M.H, (2006). Water properties. In Shaltout and Khalil (eds) *Bardawil lagoon*. EEAA publication, 604 pp. [A multi-author monographs book, covering all aspects of the lagoon, hydrology and biodiversity]

Andreini, M., van de Giesen, N.C., van Edig, A., Fosu, M., and Andah, W. (2000). Volta Basin Water Valance; ZEF-Discussion Papers on Development Policy, Number 21. Bonn, Germany. Center for Development Research. [This paper is a preliminary exploration of some of the Volta River Basin hydrologic data].

Antwi, L. (1990). Limno-chemistry of Volta Lake 25 years after its formation. Technical Report of the Institute of Aquatic Biology, Accra, Ghana: 11 p.

Beaugrand, G. and Reid, P.C. (2003). Long-term changes in phytoplankton, zooplankton and salmon related to climate. *Global Change Biology* 9: 801-817. [This is a complete guide of the effects of climatic changes on aquatic ecosystem]

Bene, C. (2007). Diagnostic study of the Volta Basin fisheries. Part 1 - Overview of the fisheries resources. Volta Basin Focal Project Report No 6. WorldFish Center Regional Offices for Africa and West Asia, Cairo Egypt, and CPWF, Colombo, Sri Lanka, 31 p. [The report presenting a background of the fisheries resources in the Volta Basin essentially from a biological perspective].

Bullock, A., Gilman, K., McCartney, M., Waughray, D., Blyth, K., and Andrews, A. (1998). Hydrological strategy to develop and manage African wetland resources for sustainable agricultural use. Wetland Characterization and Classification for Sustainable Agricultural Development. FAO/SAFR, Rome. w w w . fao . org. [This is one of a series of key publications which review different aspects of African wetlands at the continental scale, which yield valuable information and data]

Cantrell, M.A. (1988). Effect of lake level fluctuations on the habitats of benthic invertebrates in a shallow tropical lake. *Hydrobiologia* 158: 125-131.

Chi-Bonnardel, Regine Van (1973). *Atlas of Africa. Institut geographique national (France)*. Paris: Editions Jeune Afrique, pp.335. [An excellent and comprehensive illustrated history of Africa].

Cohen, A.S., Kaufman, L. and Ogutu-Ohwayo, R. (1996). Anthropogenic threats, impacts and conservation strategies in the African Great, Lakes: A review. In: *The Limnology, Climatology and Paleoclimatology of the East African Lakes*. Johnson, T.C. and Odada, E. (eds). Gordon and Breach, Toronto, pp. 575-624. [This is a widely used textbook dealing with different aspects of ecology of East African Lakes].

Convention on Biological Diversity (CDB). (2005). Inland Waters Biodiversity Introduction. Secretariat of the Convention on Biological Diversity, Montreal.

Coulter, G. (1994). Speciation and fluctuating environments, with reference to ancient East African Lakes, in K. Martens, B. Goddeeris and G. Coulter (eds.), Speciation in Ancient Lakes, *Advances in Limnology* 44:127-137.

Coulter, G.W. (1991). *Lake Tanganyika and its Life*. 1st edition. Oxford University Press, New York. [A very useful compilation of different subjects on Lake Tanganyika].

Coulter, G.W. (1994). Lake Tanganyika. In: *Speciation in Ancient Lakes*. Edited by Martens, K., Goddeeris, B. and Coulter, G. Archiv fur Hydrobiologie 44: 13-18.

Davies, B.R. and Day, J. (1998). *Vanishing Waters*. University of Cape Town Press, Cape Town.

De Jonge, V. N., Elliot M. and Orive, E. (2002). Causes, historical development, effects and future challenges of a common environmental problem: eutrophication. *Hydrobiologia* 475–476: 1–19.

Dudgeon D, Arthington A.H, Gessner M.O, Kawabata Z.I, Knowler D.J, Leveque C, Naiman R.J, Prieur-Richard A.H, Soto D, Stiassny M.L.J and Sullivan CA. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. Biological Reviews, 81: 163–182.

Dugan, P.J. (1992). Wetland management: a critical issue for conservation in Africa. In: Matiza, T., Chabwela, H.N. (Eds.), Wetlands Management: A Critical Issue for Conservation in Africa, Wetlands Conservation Conference for Southern Africa. IUCN, Gland, pp. 1 –8.

ECA, (2000). Transboundary River/Lake Basin Water Development in Africa: Prospects, Problems, and Achievements. United Nations Economic Commission for Africa Addis Ababa, Ethiopia, 75pp

Eccles, D.H. (1974). An outline of the physical limnology of Lake Malawi (Lake Nyasa). Limnol. *Oceanogr*. 19: 730-742.

Edwards, M. and Richardson, A., (2004). Impact of climate change on marine pelagic phenology and trophic mismatch. *Nature* 430: 881-884

El-Bana, M. I.; Ivan N. and Fred K. (2002). Microenvironmental and vegetational heterogeneity induced by phytogenic nebkhas in an arid coastal ecosystem. Plant and Soil 247: 283–293. [This paper illustrates the vegetation cover on the Bardawil lagoon islands).

El-Ganainy A.A., Yassien M.H., and Khalil, M.T, (2002). Ecological Survey of Bardawil nature protectorate: Fishes and Fisheries. Conservation of wetland and coastal ecosystem in the Mediterranean Region. Med. Wet. Coast. E.E.A.A. 72pp. [Technical report Provides comprehensive overviews of Bardawil lake fisheries].

El-Shabrawy, G.M. (2006). Ecological study on zooplankton community in Bardawil lagoon, Egypt. *Thalassia Salentina* 29: 3-17. [This paper illustrates the long term changes of zooplankton in the lagoon].

FAO (1997). Irrigation potential in Africa: A basin approach The Nile Basin and The Congo/Zaire River basin. Information Division, Food and Agriculture Organization of the United Nations, Viale delle Terme di Caracalla, 00100 Rome, Italy.

Fouda, M. Wanes, M. and Saleh, M. (1985). Ecology of Bardawil lagoon. A report to the Oil pollution Res. Unit, Pemboke, UK. for BP Petroleum LTD. Egypt. 94 pp.

Fryer, G. (1972a). Conservation of the Great Lakes of East Africa: a lesson and a warning. *Biol. Cons. 4*: 256–262.

Fryer, G. (1972b). Some hazards facing African lakes. *Biol. Cons*. 4: 301–302.

Furse, M.T., Morgan, P.R. and Kalk, M. (1979). The fisheries of Lake Chilwa. In Kalk,M., McLachlan, A.J. and Howard-Williams, C. eds. *Lake Chilwa: studies of change in a tropical ecosystem*, pp. 209-229. The Hague-Boston-London. Dr. W.Junk Publishers.

Global Environment Facility (GEF) (2002). Reversal of Land and Water Degradation Trends in the Lake Chad Basin Ecosystem, Project Brief. Available at h t t p : / / w w w . gefonline . org / project - Details . cfm ? projID = 767.

Gilabert, J. (2001). Seasonal plankton dynamics in a Mediterranean hypersaline coastal lagoon: the Mar Menor. *Journal of Plankton Research* 23: 207–217.

Gougswaard, P.C. and Avoke, S. (1993). Length frequency of processed fish in Yeji weekly market.Field Document of IDAF, UNDO/FAO GHA/88/004, Integrated Development of Artisanal Fisheries project.

Hails, A.J. (1996). Wetlands, Biodiversity and the Ramsar Convention. Ramsar Convention Bureau, Gland.

Hecky, R.E. and Bugenyi, F.W.B. (1992). Hydrology and chemistry of the African Great Lakes and water quality issues: Problems and solutions. Mitt. Internat. Verein. *Limnol*. 23: 45-54.

Herrera-Silveira, J.A. (1994). Spatial heterogeneity and seasonal patterns in a tropical coastal lagoon. *Journal of Coastal Research* 103: 738–746.

Hinrichsen, D., Robey, B., and Upadhyay, U.D. (1997). Solutions for a Water-Short World. Population Reports, Series M, No. 14. Baltimore: Johns Hopkins School of Public Health, Population Information Program.

Horne, A. J. and Goldman, C. R., (1994). Limnology. 2nd ed. McGraw-Hill, Inc., NY.

Howard-Williams, C. eds. Lake Chilwa studies of change in a tropical ecosystem, h t t p : / / assets . panda . org / downloads / waterinafricaeng . pdf

IieckY, R.E., and Fee, E.J. (1981). Primary production and rates of algal growth in Lake Tanganyika. *Limnol. Oceanogr*. 26: 532-547.

ILEC International Lake Environment Committee Foundation (2003). World Lake Database. International Lake Environment Committee, United Nations Environment Programme and Environment Agency of Japan, Shiga, Japan.

IPCC, (2001). Climate Change. Third assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge. 881 p.

Irvine, K. (1995). Standing biomasses, production, spatial and temporal distributions of the crustacean zooplankton. The Fishery Potential and Productivity of the Pelagic Zone of Lake Malawi/Niassa. Scientific Report of the UK/SADC Pelagic Fish Resource Assessment Project, pp. 85-108.

Irvine, K. and Waya, R. (1995). The zooplankton: general sampling methods and estimations of biomass and development rates. The Fishery Potential and Productivity of the Pelagic Zone of Lake Malawi/Niassa. Scientific Report of the UK/SADC Pelagic Fish Resource Assessment Project, pp. 69-83.

Jackson, P.B.N. (1973). The African Great Lakes: food source and world treasure. *Biol. Cons*. 5: 302–304.

Johnson T.C., C.A. Scholz C.A., Talbot M.R., Kelts K., Ngobi G., Beuning K., Ssemanda I. and McGill J.A. (1996). Later Pleistocene desiccation of Lake Victoria and rapid evolution of cichlid fishes. *Science* 273:1091-1093.

Kabii, T (1996). An overview of African wetlands. h t t p : / / hdl . handle . net / 1834 / 457

Kalk, M. (1979). Experimental trawling in 1975-76. In Kalk, M., McLachlan, A.J and Howard-Williams, C. eds. *Lake Chilwa studies of change in a tropical ecosystem,* pp. 225-227. The Hague-Boston-London. Dr. W. Junk Publishers.

Kalk, M., McLachlan, A.J and Howard-Williams, C. (1979). Lake Chilwa studies of change in a tropical ecosystem. *Monographae Biologicae* 35:17-227.

Kassas, M. et al. (2002). Management Plan for Zaranik Protected Area. Med Wet Coast, Global Environment Facility & Egyptian Environment Affairs Agency, Cairo, Egypt. [An excellent report, covering all aspects of Zaranik Protected Area, hydrology and biodiversity]

Kjerfve, B., (1994). Coastal lagoons. In Kjerfve, B. (ed.), *Coastal Lagoon Processes*. Elsevier Science, Amsterdam: 1–8.

Lehman, J.T., Mugidde, R., and Lehman, D.A. (1998). Lake Victoria plankton ecology: Mixing depth and climate-driven control of lake condition. In J. T. Lehman (ed.), *Environmental Change and Response in East African Lakes*. Kluwer, Dordrecht, pp. 99–116.

Mather, J.R. (1978). *The climatic water budget in environmental analysis*. Lexington Books, Lexington, Massachusetts.

McCully, P. (1996*). Silenced rivers: The ecology and politics of large dams*. London: Zed Books.

Mockrin, M. and Thieme, M. (2001). Lake Chad flooded savanna (AT0904). World Wildlife Fund (WWF). Available at w w w . worldwildlife . org / wildworld / profi les / terrestrial / at / at0904_full . html.

Morgan, A. and Kalk, M. (1970). Seasonal changes in the waters of Lake Chilwa (Malawi) in a drying phase 1966--1968. *Hydrobiologia* 36: 81-103.

Msiska, O.V. (2001). A review of the limnology of Malawi. Pp. 121-189 In, Wetzel, R.G., and B. Gopal (eds.), *Limnology in developing countries* 3. Societas Internationalis Limnologiae.

Musa I K et al. (2008). Saving Lake Chad. Proceedings of Sirte Roundtable (LCBC and ICID), 17 December, Libya

MWH (1998). Ghana water resources management study – International waters ‘‘building block’’ study. Main report (final). Ministry of Works and Housing, Accra, Ghana.

Nami B. (2002). Environmental Degradation of the Lake Chad Basin: Implications for Food Security.

Ngounou Ngatcha, B., (2009). Water Resources Protection in the Lake Chad Basin in the Changing Environment, *European Water*, Issue 25/26: 3-12

Nicholson, S.E. (1998). Fluctuations of rift valley Lakes Malawi and Chilwa during historical times: a synthesis of geological, archaeological and historical information’’. In Lehman, J.T. ed. *Environmental change and response in East African lakes*, pp. 208. The Netherlands: Kluwer Academic Publishers.

Nixon, S.W. (1988). Physical energy inputs and the comparative ecology of Lake and marine ecosystems. *Limnol. Oceanogr*. 33: 1005–1025.

Njaya, F.J. (1998). Co-management programmes in Malawi: a comparative case study for Lakes Malombe, Chilwa and Chiuta''. In Eide, A. and Vassdal, T. eds. The Ninth Biennial Conference of the International Institute of Fisheries Economics and Trade. pp. 260-269. Norway: Norwegian College of Fishery Science.

O'Reilly, C.M., Alin, S.R., Plisnier, P.-D., Cohen, A.S. and McKee, B.A. (2003). Climate change decreases aquatic ecosystem productivity of Lake Tanganyika, Africa. Nature 424: 766-768.

Oguntunde, P.G. (2004). Evapotranspiration and complementarity relations in the water balance of the Volta Basin: field measurements and GIS-based regional estimates Ecology and Development Series, vol. 22. Cuvillier Verlag, Goettingen, p. 169.

Ogutu-Ohwayo, R and Balirwa J.S. (2006). Management challenges of freshwater fisheries in Africa. *Lakes & Reservoirs: Research and Management* 11: 215–226.

Oki T and Kanae S. (2006). Global hydrological cycles and world water resources. *Science*, 313: 1068–1072.

Oliveira AM and Kjerfve B. (1993). Environmental responses of a tropical coastal lagoon system to hydrological variability: Mundau-Manguaba, Brazil. Estuarine, *Coastal and Shelf Science* 37: 575–591

Olivry J.C., Chouret A., Vuillaume G., Lemoalle J., and Bricquet J.P. (1996). *Hydrologie du Lac Tchad*. ORSTOM, Paris, 259 p.

Patterson, G. and Kachinjika. O. (1995). Limnology and phytoplankton ecology, p. 1-67. In A. Menz (ed.). *The fishery potential and productivity of the pelagic zone of Lake Malawi/Niassa*, NRI/ODA. 386 p.

Patterson, G., Wooster. M.J and Sear, C.B. (1995). Real-time monitoring of African aquatic resources using remote sensing: with special reference to Lake Malawi.Chatham, UK: Natural Resources Institute. 21 p.

Perez-Ruzafa, A. Carmen-Mompean, M. and Marcos C. (2007). Hydrographic, geomorphologic and fish assemblage relationships in coastal lagoons. *Hydrobiologia* 577: 107–125.

Plisnier P., Chitamwebwa D., Mwape L., Tshibangu K., Langenberg V. and Coenen E. (1999). Limnological annual cycle inferred from physical-chemical fluctuations at three stations of Lake Tanganyika. Hydrobiologia, 407: 45-58.

Plus, M. La Jeunesse, I. Bouraouic, F. Zaldívar, J. Chapelle A. and Lazure P (2006). Modelling water discharges and nitrogen inputs into a Mediterranean lagoon Impact on the primary production Ecological Modelling 193 (1-2): 69-89

Ratcliffe, C. (1971). The Fishery of the Lower Shire Area Malawi. Fisheries Bulletin No. 3. Government of Malawi, Ministry of Agriculture. Fisheries Department, Zomba.

Ribbink, A., Marsh, B. Marsh, A. Ribbink A. and Sharp, B. (1983). A preliminary survey of the cichlids fishes of rocky habitats in Lake Malawi. *Afr. J. Zool*. 18: 149–310.

Saad, M.A. (2006). Phytoplankton and Periphytic Algae In Shaltout K. and Khalil, M (eds) *Bardawil lagoon*. EEAA publication 604pp.

Salama W. and Grieve A. (1996). The Zaranik Experience. *Sandgrouse* 18: 14–17.

Salonen, K., Sarvala, J., Järvinen, M., Langenberg, V., Nuottajärvi, M., Vuoirio, K. and Chitawebwa, D.B.R. (1999). Phytoplankton in Lake Tanganyika : Vertical and horizontal distribution of in vivo fluorescence. *Hydrobiologia*, 407: 89−103.

Sarch M.T. and Birkett C.M. (2000) 'Fishing and Farming at Lake Chad: Responses to Lake Level Fluctuations' Geographical Journal 166(2).

Schuyt, K. (2002). Land and Water Use of Wetlands in Africa: Economic values of African wetlands. IIASA Interim Report IR-02-063. International Institute for Applied Systems Analysis,Austria. h t t p : / / w w w . iiasa . ac . at / Admin / PUB / Documents / IR-02-063 . pdf

Schuyt, K. (2005). Economic consequences of wetland degradation for local populations in Africa *Ecological Economics* 53: 177– 190.

Seehausen, O. (1996). Lake Victoria rock cichlids: taxonomy, ecology, and distribution. Verduyn Cichlids, Zevenhuizen, the Netherlands.

Shaltout, K.H. and Khalil, M.T. (2005).Lake Borullus (Borullus Protected Area). Publication of National Biodiversity Unit, No. 13, Egyptian Environmental Affairs Agency, Egypt, 578 pp. [A text book, covering all aspects of the lake, hydrology and biodiversity]

Sikes, S. (2003). *Lake Chad versus the Sahara Desert*. Newbury: Mirage Newbury.

Snoeks J., Rüber L., Verheyen E. (1994) The Tanganyika problem: comments on the taxonomy and distribution patterns of its cichlid fauna. In*: Speciation in Ancient Lakes* (eds Martens K, Goddeeris G, Coulter G), pp. 355–372. Schweizerbart, Stuttgart.

Souza M.F.L, Kjerfve B, Knoppers B, Landim de Souza W.F, Damasceno R.N (2003). Nutrient budgets and trophic state in a hypersaline coastal lagoon: Lagoa de Araruama, Brazil*. Estuar Coast Shelf Sci* 57:843–858.

Spigel R.H, Coulter G.W. (1996). Comparison of hydrology and physical limnology of the East African Great Lakes: Tanganyika, Malawi, Victoria, Kivu and Turkana (with reference to some North American Great Lakes). In: Johnson TC, Odada EO (eds) *The Limnology, Climatology and Paleoclimatology of East African Lakes*: Gordon and Breach, Toronto, pp 103–139.

UNEP. (1999). Early Warning of Selected Emerging Environmental Issues in Africa: Change and Correlation from a Geographic Perspective. UNEP/DEWA Environment Information and Assessment Technical Report, TR. 99-2, p. 42.

UNEP. (2006). Africa Environmental Outlook 2: Our Environment, Our Wealth. United Nations Environmental Programme. 542 pp.

UNEP GEMS / Water Programme. (2008). Water Quality for Ecosystem and Human Health, w w w . unwater . org / downloads / water_ quality _ human _ health . pdf. (One of the basic reports provides an introduction to a diverse range of global water quality issues, including approaches to their identification, analysis and resolution].

Verschuren, D. (2003). The heat on Lake Tanganyika. Nature 424: 731-732.

Wagner, I., Marsalek J. and P. Breil, p. (2007). Aquatic Habitats in SustainableUrban Water Management: Science, Policy and Practice Taylor & Francis Group, London, Leiden / New York / Philadelphia / Singapore

Walling, D.E. (1996). Hydrology and rivers. In Adams W, Goudie A, Orme A (eds). *The physical geography of Africa*. Oxford University Press, Oxford pp. 101-121

Wandiga S.O. (2003). Lake Basin Management Problems in Africa: Historical and Future Perspectives.w w w . worldlakes . org / ... / Lake % 20Basin % 20Problems % 20in % 20Africa_12 . 16. 03. pdf

Wikipeda (2005). Africa - Wikipedia. Available at h t t p : / / e n . wikipedia . org / wiki / Africa

Williams, W.D. (1996). What future saline lakes? *Environment* 38: 12–20, 38–39.

Williams, W.D. (2001). Anthropogenic salinization of inland waters. *Hydrobiologia* 466: 329–337.

World Commission on Dams (2001). Dam Statistics: Africa and the Middle East Regions. Available at: h t t p : / / w w w . dams . org / kbase / consultations / afrme / dam _ stats _ eng . htm

WWF (2002). The facts on water of Africa Living Waters Conserving the source of life w w w . panda . org / livingwaters

Zahran M. and Willis A.J. (1992). *The Vegetation of Egypt*. Chapman & Hall, London. 424 pp. [Text book in which The vegetation types of the different habitats of Egypt are described].

Zaldivar, J. M., Cattaneo, E. Plus, M. Murray, C.N. Giordani, G. and Viaroli, P. (2003). Long-term simulation of main biogeochemical events in a coastal lagoon: Sacca Di Goro (Northern Adriatic Coast, Italy). *Continental Shelf Research* 23: 1847–1875.

symposium at the 1998 American Association for the Advancement of Science (AAAS), Annual Meeting, Philadelphia.

Biographical Sketches

Gamal M. El-Shabrawy, was born on 24 February 1964. He obtained his PhD degree from the Faculty of Science, Mansoura University, Egypt in 1996. Working as research assistant, researcher and team leader in many research projects that have been carried out in the Egyptian lakes, wetland ecosystems since 1993 up till now. Contributed in producing 4 and 2 chapters in 2 international reference books published by Springers and Nova Publication and one chapter in local reference book for the National Biodiversity Unit of EEAA, Lake Bardawil (2005). Teaching post graduate lectures on aquatic ecology, limnology and lake management. Collaborating and consultant in the EIA studies of many tourist Village and Petroleum Company. Attending many training courses and scholarships in Egypt, Jordan and Belgium as well as several national and international symposia, conferences and congresses in Egypt and abroad. Supervisours of 14 M.Sc.'s and Ph.D.'s in the fields of population and community of zooplankton and Macrobenthos. Member of many national and international councils, committees and societies in the field of limnology and Aquatic Environmental Sciences. Consultant of many international and local journals. Forty two publications, in national and international specialized journals.

Khalid A. A. Al-Ghanim received M.Sc. degree in Zoology (Environment and Pollution), College of Science, King Saud University, Saudi Arabia and Ph.D. degree from the same University in 2006. Teaching under- and post-graduate lectures on aquatic ecology and general biology. Member of many national and international councils, committees and societies in the field of Environment and Pollution. Attending many training courses and scholarships in King Saud University and University of Arizona USA.