The Anthropogenic Inputs in Aquatic Systems as a Source of Pollution in Lake Victoria

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Abstract

Aquatic ecosystems are of vital importance considering the inter-relationships that exist between these ecosystems and terrestrial ones. However, the physico-chemical and biological characteristics of lake basins such as Lake Victoria are influenced by both natural and anthropogenic inputs. These inputs originating from catchment areas may find their way through streams, Satellite lakes, river systems and eventually enter the lake.

Research conducted between September/October 2000 and March/April 2001 in selected satellite lakes around the lake Victoria basin (River Mara, Lake Kubigena and Kirumi ponds in Mara; Lake Malimbe in Mwanza and Lakes Burigi, and Ikimba in Kagera region) revealed that nutrients such as phosphates, nitrates, nitrites, ammonia and zinc tend to occur in these lakes though for most of them at levels not exceeding the recommended values in the Water Utilization (Control and regulation) Amendment Act of 1981. Since these lakes discharge into lake Victoria directly or indirectly, it makes them potential sources of pollution to the main lake Victoria.

This paper relates agricultural activities around selected satellite lakes in the lake Victoria basin to the changes in the physico – chemical characteristics of satellite lakes and their potential of being a source of pollution in Lake Victoria.

***Keywords**:* Agro-chemicals**,** Pollution, Anthropogenic inputs, Satellite lakes

Introduction

Aquatic ecosystems are more difficult to protect than terrestrial ones because they depend on the quality and quantity of water, which can be affected at any point on the course-way between the water catchment and the given system (Shumway, 1999). Water quality is dependent on the upstream land-use pattern and upstream runoff although other factors such as reservoir/stream/lake structure and configuration, geomorphology and ecosystem characteristics also have important influences (Nakasone and Kuroda, 1999). Changes in land-use pattern have lead fundamentally to spatial and temporal heterogeneity of the limnological characteristics thus influencing ecological structure and functioning of aquatic ecosystems (Nogueira et al. 1999). Nutrient flow, food webs, and species distribution all show linkages across aquatic and terrestrial ecosystems (Shumway, 1999).

Lake Victoria, the world's largest tropical lake and the world's second largest body of fresh water (second to Lake Superior) has a surface area of about 69,000 km$^{2.}$ It lies across the equator (0^0 21' N—$3^0$0' S; $31^0$39-$34^0$53 E) at an altitude of 1135 m above sea level between the Central African and the East African Rift valleys. It is shared by the East African countries (Tanzania - 51%, Uganda - 43% and Kenya –6%). Compared to the other Great African Lakes, Tanganyika (max. depth 1470 m) and Malawi(max. depth 704 m), Lake Victoria is shallow (max. depth 80 m; mean depth 40 m). The lake basin morphology is very different from that of the rift lakes being basically saucer shaped with a coastline that indents at many points.

The lake Victoria drainage basin covers an area of 192,580 km^2 with Tanzanian side of the drainage basin covering 115,380km^2. The Tanzanian side catchment covers the whole of Kagera region in the West, Mwanza and part of Shinyanga Regions in the South and Mara region in the East Major rivers draining into lake Victoria are Mara, Mori, Suguti, Grumet, Simiyu, Rubana, Suguti, Ngono, Magogo, Mbalageti, Moame and Kagera (Figure 1).

There are considerable variations in the total rainfall over the catchment. The minimum amount of rainfall (500-750 mm/yr) is experienced in the extreme eastern side of the lake. Westward rainfall increases to an annual average of over 2000 mm in the area embracing the Ssese Islands southward to Bukoba. In Mwanza region the yearly average is 900 – 1100 mm in the western and central parts and 750 - 900 mm in the eastern part.

The Lake Victoria catchment has diverse forms of water bodies ranging from flood pools to small and big satellite lakes surrounded by a variety of wetland vegetation. Recent studies have, ascertained that these important ecosystems such as satellite lakes, rivers, adjacent wetlands, ponds and dams found around Lake Victoria catchment are faunal reservoirs for endangered fish species (Kaufman and Ochumba, 1993, Kaufman et al., 1997; Chapman et al., 1995). Unlike Lake Victoria whose scientific research dates as early as the 1920's (Lowe - McConnell, 1997; Ogutu-Ohwayo, 1990), research in satellite lakes lag behind and therefore there is an urgent need for more attention in order to furnish information which will contribute to the effective conservation of biological diversity. Critical analysis of data has shown that research on the satellite lakes has been mainly on species composition, revealing that satellite lakes habour quite a number of endangered species some of which are no longer found in Lake Victoria (Kaufman, 1992; Kaufman et al., 1997; Benon 1997). Minimal information is however available on the limnological parameters, fish feeding relationships and behaviour, ecology and the genetic composition of different species to ascertain their originality.

The objective of this paper is to relate agricultural activities in selected satellite lakes around the lake Victoria basin to the changes in the physico – chemical characteristics of satellite lakes and their potential of being a source of pollution in Lake Victoria.

Materials and Methods

Sampling Sites

A few satellite lakes were selected as pilot sites for the survey: These were: Mara river, Kirumi ponds and Lake Kubigena in Mara region, Lake Malimbe in Mwanza region and Lake Burigi, and Ikimba in Kagera region (Figures 2,3,4 and 5). Two surveys were conducted that is during September/October 2000 (dry season) and March/April 2001 (rain season).

Land-use maps for these areas were obtained from the GIS unit of the National Environment Management Council (NEMC).

Sampling Methodology

Collection of water samples

One litre capacity plastic bottles were used to collect water samples for nutrient determination. Surface samples were collected directly from the surface while a tube sampler of 1 metre length was used to collect composite samples (whole water column) at shallow depths and near macrophytes. Each bottle was thoroughly washed and rinsed with water before sample collection.

Measurement of parameters

Direct measurement was for pH, which was measured using Wagtech Portable probe that permitted measurement of the parameter on site.

Measurement of the concentration of zinc, nitrate, nitrite, ammonia and phosphate was done in the laboratory using the Palintest Photometer 5000. Procedures for the sample treatment to obtain the results were as described in the manual on instructions for using the Palintest Photometer 5000 instrument (Photometer 5000 instructions manual).

Readings from the Wagtech probe and the photometer were compiled and entered into a computer and finally analysed.

Results

Tables 1 and 2 give a summary of the results for the parameters measured during the two surveys.

Table 1: Chemical parameters measured during the survey (Sept.-Oct. 2000)

	Water parameters											
SITE	PH		NITRITE		PHOSPHATE		NITRATE		AMMONIA		ZINC	
	Sur	Bot	Sur	Bot	Sur	Bot	Sur	Bot	Sur	Bot	Sur	Bot
MR	7.82	7.83	0.003	0.001	0.22	0.28	0.004	0.009	0	0	0	0
Bus	7.82	7.13	0.44	0.001	0.28	0.38	0.063	0.13	0.04	0.01	0.04	0.01
L.Mal	7.0	9.0	0.0035	0.025	-	-	0.115	0.17	1.8	1	0.01	0.01
L.Bur	8.95	8.96	0.058	0.009	0.35	0.72	0.074	0.08	0.04	0.15	0.01	0.01

The pH ranged from 7.0-9.0, the highest and lowest being from Lake Malimbe during the September/October survey. During the March/April survey values between 6.56 for Lake Kubigena and 9.16 for Lake Malimbe were recorded being the least and highest values respectively.

Table 2: Chemical parameters measured during the survey (March-April 2001)

	Water parameters											
SITE	PH		NITRITE		PHOSPHATE		NITRATE		AMMONIA		ZINC	
	Sur	Bot	Sur	Bot	Sur	Bot	Sur	Bot	Sur	Bot	Sur	Bot
MR	7.06	7.04	-	-	0.45	0.48	0.003	-	-	-	0.115	0.04
Bus	6.9	6.56	0.001	0.004	0.40	0.24	-	0.006	-	-	0.01	0.02
L.Mal	8.16	9.16	-	0.004	0.55	1.03	0.006	0.040	0.06	-	0.01	0.01
L.Bur	8.82	8.7	0.016	0.011	0.92	1.0	0.003	0.003	0.03	-	0.005	0.01
L.Ikim	8.0	7.6	0.001	0.001	0.26	0.26	0.038	0.059	0.26	0.26	0.03	0.02
K.Ponds	8.29	7.73	0.0005	-	0.35	0.44	0.051	0.015	-	-	0.095	0.04

KEY

L. Bur. – Lake Burigi
L. Mal. – Lake Malimbe
MR – Mara River
Bot - Bottom
K. Ponds – Kirumi ponds
Bus – Buswahili
L. Ikim – Lake Ikimba
Sur – Surface

High levels of phosphates were recorded from Lake Burigi (0.72 mg/l) while lowest values were from Mara river (0.22 mg/l) during the September/October. During the March/April survey Lake Malimbe had the highest level reaching 1.03 mg/l while the lowest value of 0.24 mg/l was recorded from Lake Kubigena.

Lake Malimbe had the highest concentration of ammonia whereby 1.8mg/l was recorded during the September/October survey. During the same period the least concentration of ammonia(0.01mg/l) was recorded in Lake Kubigena. Concentrations between 0.03 – 0.26 mg/l ammonia were recorded from Lake Burigi and Lake Ikimba for the March/April survey respectively.

Nitrites were highest in Lake Burigi (0.058 mg/l) while the least concentration was recorded in Mara River (0.001mg/l) for the September/October survey. During the March/April survey highest nitrite concentration was recorded in Lake Burigi (0.016mg/l) and the least nitrite concentration was from Kirumi ponds (0.0005 mg/l).

Nitrate concentration was highest in Lake Malimbe (0.17mg/l) with the least concentration found in Mara River (0.004 mg/l) during the September/October survey. Highest concentration was also recorded in Kirumi ponds (0.051mg/l) and least concentration in Lake Burigi (0.003 mg/) during the March/April survey.

During the September/October survey zinc levels were high in Lake Kubigena (0.04mg/l) while lake Malimbe and Burigi had the least zinc levels (0.01 mg/l). In the March/April survey also highest levels of zinc were recorded in Mara river 0.115 mg/l while Lake Burigi had low zinc concentration reaching 0.005 mg/l.

Discussion

As in many parts of Tanzania majority of the people in the lake zone live in rural areas and their livelihood depends on primary economic activities such as subsistence agriculture, pastoralism, fishing, and small-scale mining. Urban economic activities are mainly manufacturing and commerce. The major food crops include cassava, maize, sorghum, millet and banana. Cotton and coffee are the major cash crops (mainly produced in lowland areas surrounding satellite lakes). The multiplicity of activities in the lake basin has attributed to the instability in the Lake Victoria ecosystem, which has undergone substantial changes (Seehausen, 1996).

From the data gathered from the satellite lakes for the two surveys, results show that ecological parameters varied during the two seasons i.e during the dry season (September/October) and during the rain season (March/April 2001). As shown in Tables 1 and 2, nutrients such as nitrites, phosphates, nitrates, ammonia and zinc tend to occur in varying proportions in satellite lakes. Other satellite lakes with direct connection to Lake Victoria such as Mara and Kagera rivers may contribute a significant amount directly through their discharge into lake Victoria if accumulation of pollutant in the satellite lakes becomes significant. Lake Burigi, the largest satellite lake in the lake Victoria basin connect to both river Kagera and Lake Victoria through the drainage by river Mwisa. Lake Ikimba also drains in the Kagera. River Mara forms (along its course) Lake Kubigena and Kirumi ponds and finally discharges into Lake Victoria. Lake Malimbe has no direct connection to the main lake but could be contributing to pollution of the main lake through leaching since its source of water is through seepage and rains (Katunzi 1998).

The levels of pH observed in most lakes during both surveys were within the Tanzania's Temporary standards for receiving waters of 6.5 - 8.5 (Water Utilization (Control and Regulatins) Amendment Act, 1981) – Table 3.

Substance	**Units**	**Maximum Permissible Concentration in Receiving Waters**	
		Category 1	**Category 2**
PH	**mg/l**	**6.5-8.5**	**6.5-8.5**
Dissolved Oxygen	**mg/l**	**6**	**5**
Zinc	**mg/l**	**0.2**	**0.2**
Ammonia	**mg/l**	**0.5**	**0.5**
Nitrates	**mg/l**	**50**	**50**

Table 3: Tanzania Temporary Standards for receiving waters

Key:
Category 1 – Water to be suitable source for drinking water supplies, swimming pools, food and beverage industries, pharmaceutical industries requiring water source of comparable quality.
Category 2 – water to be suitable for use with cattle, fisheries, shell cultures, recreation and water contact sports.

Exceptions were for Lake Burigi for the September/October survey and Lake Malimbe for the March/April survey. High pH levels in Lakes Burigi and Malimbe tallies with high alkalinity levels observed in the two lakes, which could have been a result of high calcium carbonate levels in the water. Comparatively, though in different drainage areas, Payne, 1974 obtained ranges of pH between 7.6 - 7.7 from a survey done in Malya dam in December 1967 and April 1968 respectively. Almost similar values (to those obtained in this study) were recorded from Nyumba ya Mungu dam in June 1972 and April 1973 (8.4 - 8.9). In Ruvu river values ranged between 6.7 - 6.8 in June and April respectively

(Petr, 1975). Likewise high levels of alkalinity were recorded at Nyumba ya Mungu dam and Ruvu river during June and April. Variation in pH values might have also been a result of fertilizer application to cultivated lands adjacent to the satellite lakes (Nakasone and Kuroda 1999). As shown in Figures 2,3,4 and 5 most lowlands fringing satellite lakes are used for agricultural activities and consequently prone to inputs of fertilizers (organic and inorganic) and agrochemicals such as pesticides, fungicides and herbicides to enhance agricultural production. Table 4 shows the types and annual fertilizer consumption in tonnes) in the Lake Victoria basin from 1984 – 1990.

Region	**Fertilizer type**	**84**	**85**	**86**	**87**	**88**	**89**	**90**
	Sulphate of Ammonia							
Kagera		**20**	**40**	**43**	**-**	**12**	**200**	**159**
Mara		**820**	**-**	**360**	**520**	**103**	**120**	**84**
Mwanza		**519**	**758**	**526**	**810**	**1318**	**761**	**271**
	Calcium Ammonia nitrate (CAN)							
Kagera		**440**				**360**	**240**	**81**
Mara		**-**	**-**	**200**	**260**	**-**	**-**	**28**
Mwanza				**1482**	**267**	**935**	**-**	**27**
	Triple Super Phosphate							
Kagera		**80**	**546**	**441**	**-**	**-**	**-**	**-**
Mara		**200**	**533**	**46**	**162**	**-**	**-**	**90**
Mwanza		**-**	**816**	**998**	**535**	**23**	**31**	**189**
	Urea							
Kagera		**80**	**163**	**423**	**-**	**-**	**-**	**-**
Mara		**82**	**218**	**200**	**385**	**14**	**80**	**123**
Mwanza		**44**	**60**	**68**	**90**	**110**	**572**	**281**

Table 4: Annual Fertilizer consumption in the Lake Victoria basin in tonnes

Source: Tanzania Bureau of Statistics

The varieties included sulphate of ammonia, calcium ammonium nitrate, triple super phosphate and urea, which were used in the three regions of Kagera, Mwanza and Mara. Misuse of both fertilizers and agrochemicals leave unused residues in soils and through leaching, their remains finally enter the satellite lakes and finally feature in Lake Victoria.

Nitrates measured in the satellite lakes during both surveys were at low levels. Comparatively, Petr, 1975 recorded values of nitrates reaching 10 mg/l in June 1972 and 13 mg/l in April 1973 from Nyumba ya Mungu dam and 4.5 mg/l in June 1972 and 8.0 mg/l in April 1973 from Ruvu river. Both values from Nyumba ya Mungu and from Ruvu river are higher than any value recorded during the two surveys. However, all values (obtained from the two surveys and those obtained by Petr 1972 and 1973) are low compared to the Tanzania's Maximum Permissible Concentration of nitrates in receiving waters of 50 mg/l (Water Utilization(Control and Regulation) Amendment Act, 1981
In the surveyed lakes, Phosphate values of less than 0.4 mg/l were obtained (except for Lake Burigi, where 0.72 mg/l of phosphates in its composite sample was recorded during the September/October survey. During the March/April survey phosphates were higher

with values greater than 1.0 mg/l recorded in Lake Malimbe. Although the cause of higher phosphate levels in lake Burigi could not be ascertained, the most probable source could be from natural cause since the place has no agricultural activities, for lake Malimbe both from natural as well as agricultural activities within the vicinity of the lake could have played a role. Through leaching for the case of Malimbe and through discharge to the lake via the Kagera for the case of Burigi, Lake Victoria could receive significant amounts of phosphates.

Zinc values observed in different satellite lakes were lower compared to the Maximum Permissible limit for Zinc in receiving waters of 0.2 mg/l.

Ammonia was another parameter measured during the two surveys. Decay of submerged vegetation and leaching from nearby agricultural areas might have contributed to high levels of ammonia recorded in Lake Malimbe during the September/October survey. Other places sampled during this survey comparatively had low ammonia levels. The dilution effect from the long rains (during the March/April survey) could be the reason for the low levels recorded. The level of Ammonia recorded for Lake Malimbe (1.8 mg/l) is higher than the Maximum Permissible Concentration (0.5 mg/l for category 1 and 2 – Table 5) given in the Tanzania Temporary standards for receiving waters (Water Utilization (Control and Regulation) Amendment Act, 1981).

Machiwa, 2001 assessed pollution loading from terrestrial sources and found that rivers Simiyu and Kagera found within the Lake Victoria catchment (which have a lot of agricultural activities on their fringes) contributed significantly to siltation due to their sediment loads. The two rivers' sediment loads were found to be 5674 tonnes/day and 2111 tonnes/day for Simiyu and Kagera respectively. Phosphorous levels were also analysed showing that river Simiyu had the highest phosphorous load of 32.99 tonnes/day (Total Phosphorous) and soluble reactive phosphorous was found to be 0.4486 tonnes/day. River Kagera gave values of 1.6475 tonnes/day (Total phosphorous) and 0.1515 tonnes/day soluble reactive phosphorous. Through their discharges into Lake Victoria most of these sediments end up in the lake

Anthropogenic inputs have resulted in changes in the limnology of the lake Victoria (Kaufman et al. 1997). Surveys have shown that lake Victoria was stable during the pre-colonial period (Hecky 1993). Changes in the limnology of the lake started surfacing in the 1900 a period coinciding with cultivation, industrialization and rapid population growth whereby sewage and other domestic wastes increased. By 1920's nitrogen and phosphorous levels had started increasing due to anthopogenic inputs and blue green algae started to appear in the lake (Seehausen, 1996).

By 1960s, there was massive eutrophication and oxygen was severely depleted with rapid growth of blue-green algae (Benon, 1997). During the 1970s the nutrient load continued to increase and likewise increased algae growth, their decomposition of which made deeper waters devoid of oxygen except in shallow inshore waters. Early 1980's algae biomass increased 5 – 10x in open waters causing massive eutrophication (Baskin, 1992). By 1990 water hyacinth from feeder rivers envaded the lake choking water ways and fish landings.Water transparency, which was 8m by 1920s (Seehausen et al 1997, Graham, 1929) decreased to 5m in the 1930s decreasing further to < 1m by 1990s (Benon, 1997) in deep open waters. In the littoral zone transparency decreased from 3m in the 1920s to < 1m by 1990s (Seehausen et al. 1997). Limnological studies conducted by Talling in the 1960s (Talling, 1966) showed that radical changes had taken place with regard to limnology and fisheries of the lake as a result of increased population in the riparian countries whereby water quality had deteriorated.

Witte et al 1999 reports that human activities are the cause of increased eutrophication of the lake whereby algae blooms caused a decrease in dissolved oxygen concentration resulting into massive fish kills.

Conclusion and Recommendations

Water quality in Lake Victoria has declined greatly owing to eutrophication arising from increased inflow of nutrients into the lake. As already discussed most of these nutrients have been a result of anthropogenic activities in the catchment. The satellite lakes in the catchment have been recipients of these inputs and through inter-linkages to the Lake Victoria had acted as a “messenger” carrying nutrients through them and later discharging in the lake. It is therefore recommended that:

- A system for periodic sampling of the varying parameters should be established in order to monitor changes in satellite lakes as an early warning to expected changes in Lake Victoria
- Establish correlation between the level of the varying parameters in the main lake and the condition in the catchments of the satellite lakes
- Establish pollutant retention in the satellite lakes in order to predict the contribution of these lakes in the pollution of the main lake.
- Study processes happening in satellite lakes in order to understand pollutant dynamics in the main lake

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References

Baskin, Y. 1992. Africa’s troubled waters. Fish introductions and a changing physical profile muddy Lake Victorias future. Bioscience Vol. 42, No. 7.

Benon, C., 1997. Lake Victoria, Its history and fall. TED case studies. Nile perch, Trade and Environment. Uganda Environment Development Homepage.

Chapman, J. L., Kaufman, L. S., Chapman, C. A. and Mackenzie, F. E., 1995. Hypoxia tolerance in 12 species of East African cichlids: Potential for low Oxygen refugia in Lake Victoria. *Conservation Biology*, Vol. 9, No. 5, pp 1274 – 1288.

Ehling Consult, 1997. Lake Victoria Basin National resources under Environmental Stress. Report for sida from a Fact Finding Mission to Kenya, Tanzania and Uganda, April, 1997. Publications on Water Resources. No. 11:2.

Graham, M.,1929. the Victoria Nyanza and its Fisheries. A Report on the Fishing Surveys of Lake Victoria. London: Crown Agents for the colonies, 256pp.

Hecky, R. E. 1993. The Eutrophication of Lake Victoria. Verh. Int. Ver. Limnol. 25: 39–48.

Katunzi, E. F. B., 1998. Survey of Satellite lakes, Rivers, and Dams. In: A Report on the Survey of Fisheries Biology, Ecology and Biodiversity in Lake Victoria Basin (Tanzania waters) as well as satellite lakes, rivers and dams. 43 – 46 pp.

Kaufman, L., Ochumba, P., 1993. Evolutionary and Conservation Biology of Cichlid fishes as revealed by faunal remnants in Nothern Lake Victoria. *Conservation Biology* 7: pp. 719-730.

Kaufman, L., 1992. Catastrophic change in species rich Freshwater Ecosystems. The lessons of Lake Victoria. *Bioscience,* Vol. 42, No. 11.

Kaufman, L. S., Chapman, J., and Chapman, A., 1997. Evolution in fast forward: haplochromine fishes of the Lake Victoria region. *Endeavour* Vol. 21(1), 23-30pp.

Lowe-McConnell, R., 1997. EAFRO and after: A guide to the key events affecting fish communities in Lake Victoria (East Africa). *South African Journal of Science*. Vol. 93.

Machiwa, P. K. 2001. Assessment of pollution loading into lake Victoria from terrestrial sources. The csae of Phosphorous and Sediments. A paper presented at thye LVEMP Tanzania 2001 Scientific Conference 6th-10th August 2001.

Nakasone, H. and Kuroda, H. 1999. Relationship between water quality in irrigation reservoirs and land-use of the watershed. Lakes and reservoirs: research and management, 1999, 4: 135-141.

Nogueira, M. G., Henry, R., and Maricatto, F. E. 1999. Spatial and Temporal heterogeneity in the Jurumirim Resevoir, Sao Paulo, Brazil. Lakes and Resevoirs: research and management 1999, 4: 107-120.

Ogutu – Ohwayo, R., 1990. The decline of the native fishes of Lake Victoria and Kyoga (East Africa and the impact of the introduced species, especially the nile perch, *L.niloticus* and the Nile tilapia, Oreochromis niloticus. *Environmental Biology of fishes* 27: pp. 81 – 96.

Payne, A. I. 1974. Some characteristics of the fish fauna of a dam in the Lake Victoria region of Tanzania including the effects of multispecific stocking with Tilapia species. *The African Journal of Hydrobiology and Fisheries*. Vol. 3: No. 2: 111-122

Petr, T. 1975. Limnology and Fisheries of Nyumba ya Mungu, A man-made lake in Tanzania. *The African Journal of Hydrobiology and Fisheries*. Vol. 4: 39-50.
Photometer 5000. A manual on instructions for using the Palintest Photometer 5000 instrument. Palintest Ltd, UK.

Seehausen, O., 1996. Lake Victoria cichlids. Taxonomy, Ecology and Distribution. Verduyn cichlids. Printed in Germany.

Seehausen, O., 1997. Distribution and reproductive isolation among color morphs of a rock dwelling Lake Victoria cichlid (H. Nyererei). *Ecology of Freshwater Fishes* 6: 59-66.

Shumway, C. A. 1999. Forgotten waters: Freshwater and marine ecosystems in Africa. Strategies for biodiversity conservation and sustainable development. Boston University.

Talling, J. F. 1966. The annual cycle of stratification and phytoplankton growth in Lake Victoria (East Africa). *Int. Revue ges. Hydrobiol.* 51: 545-621. Water Utilization (Control and Regulation) Act No. 42 of 1974.

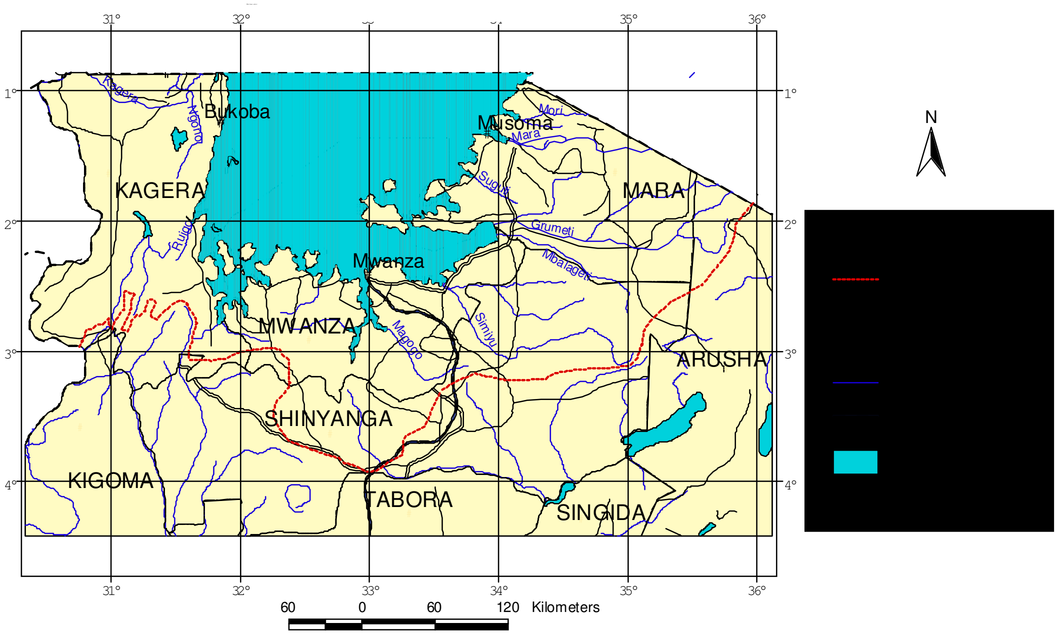

Figure 1: Lake Victoria Basin (Main Drainage Systems)

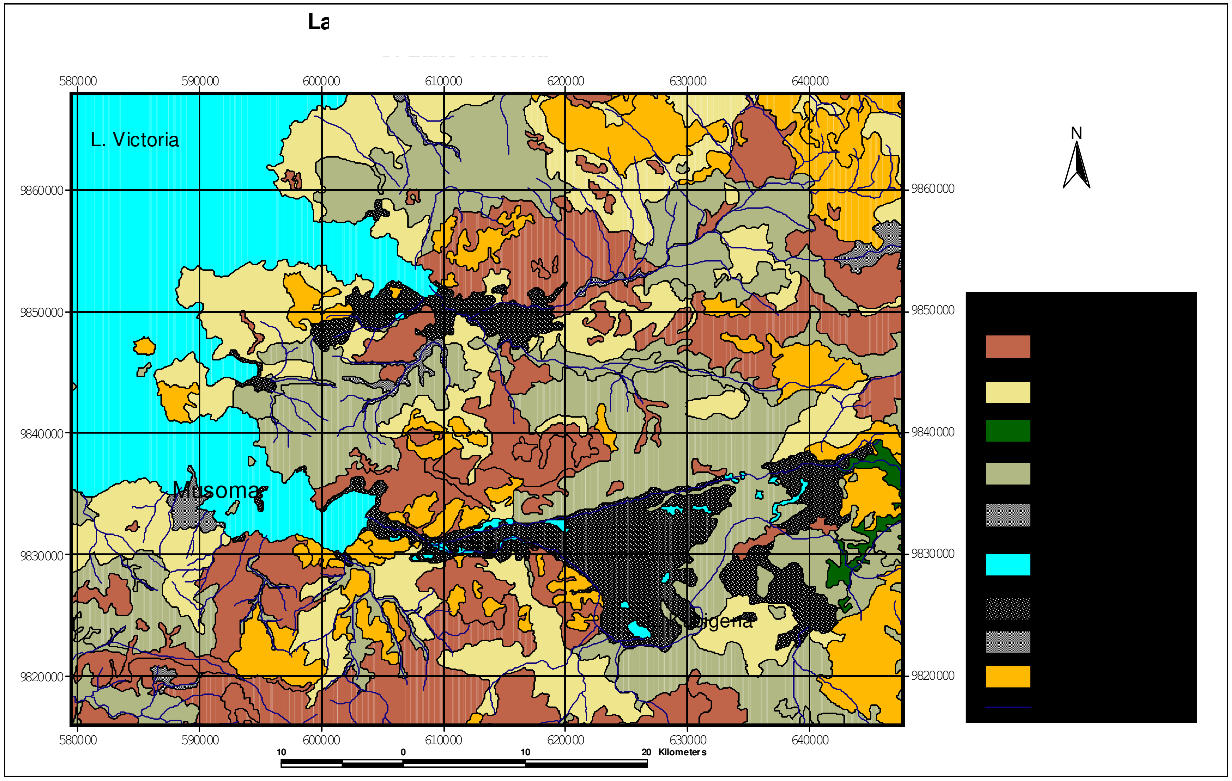

Figure 2: Land use Cover – Eastern Part of Lake Victoria

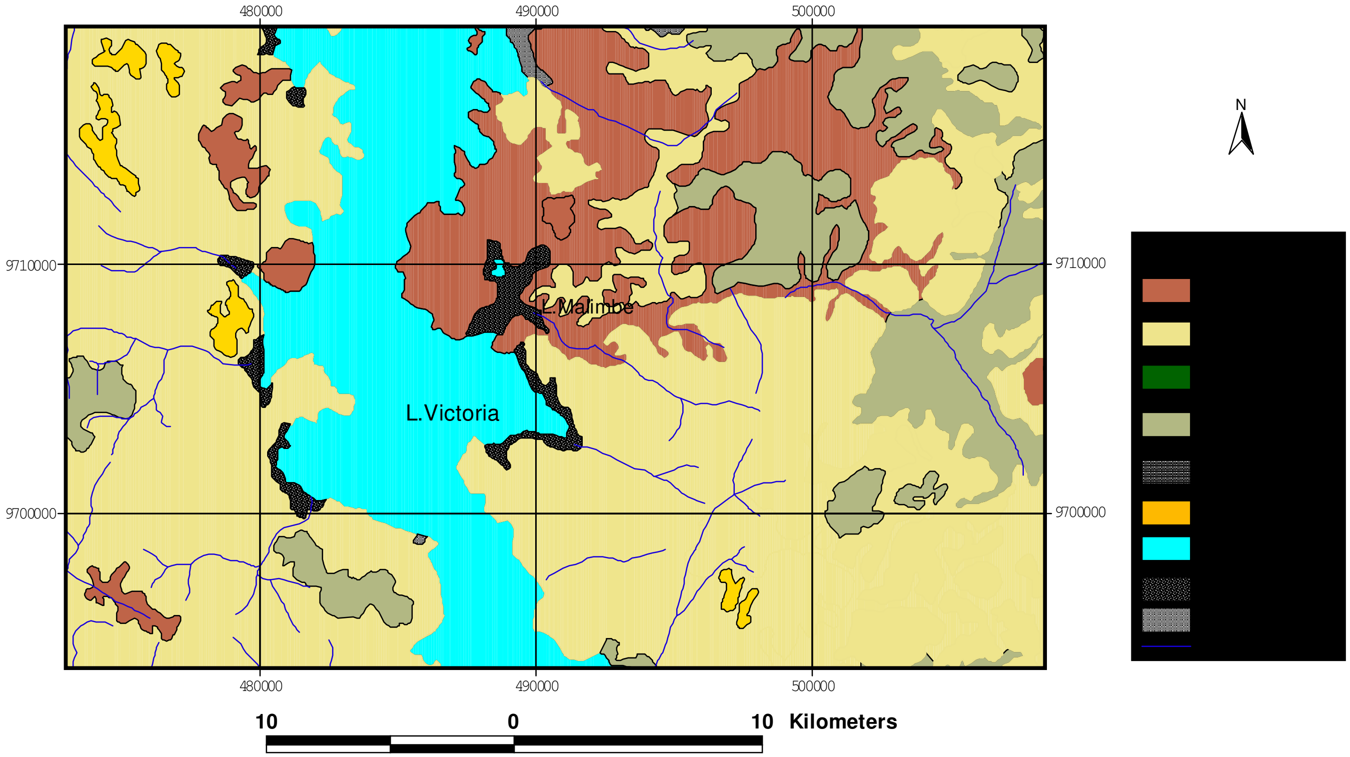

Figure 3: Land use pattern around Lake Malimbe.

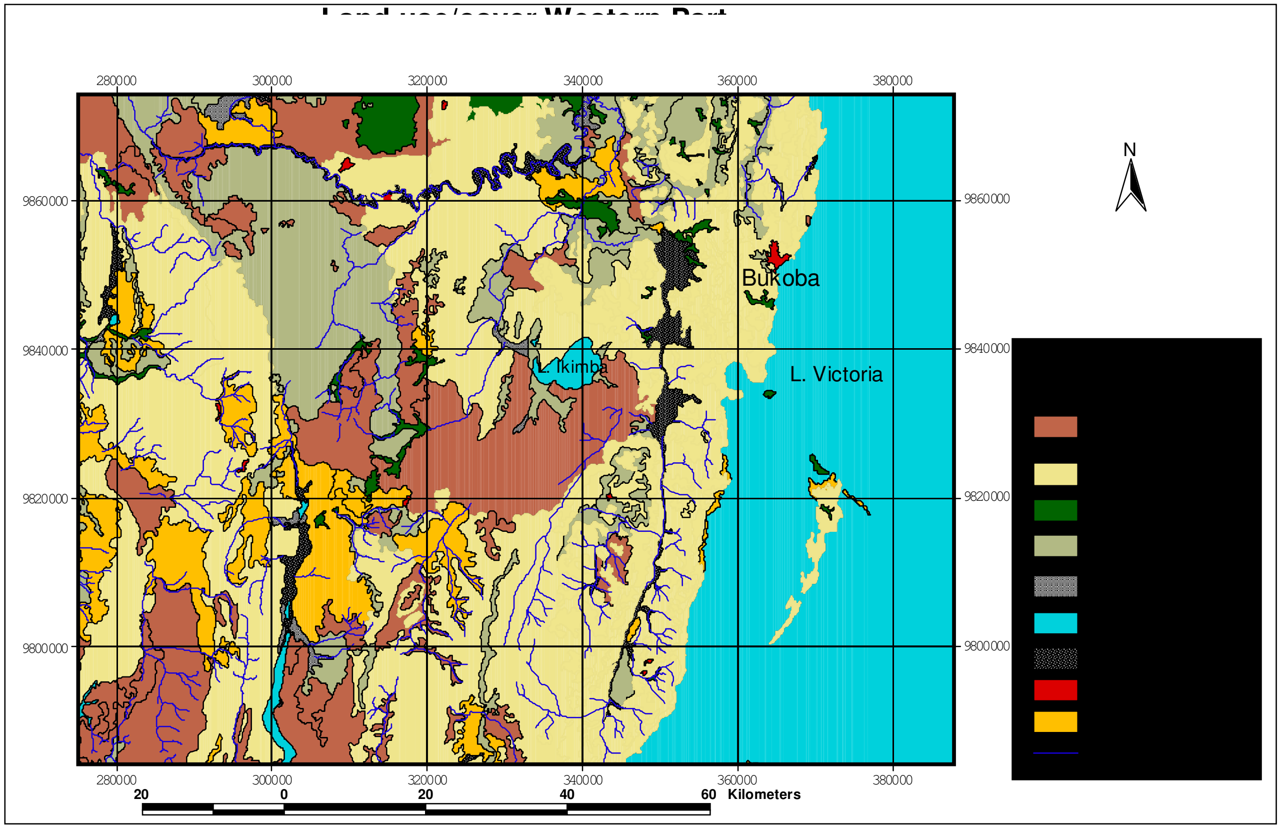

Figure 4: Land Use Cover – Western Part of Lake Victoria

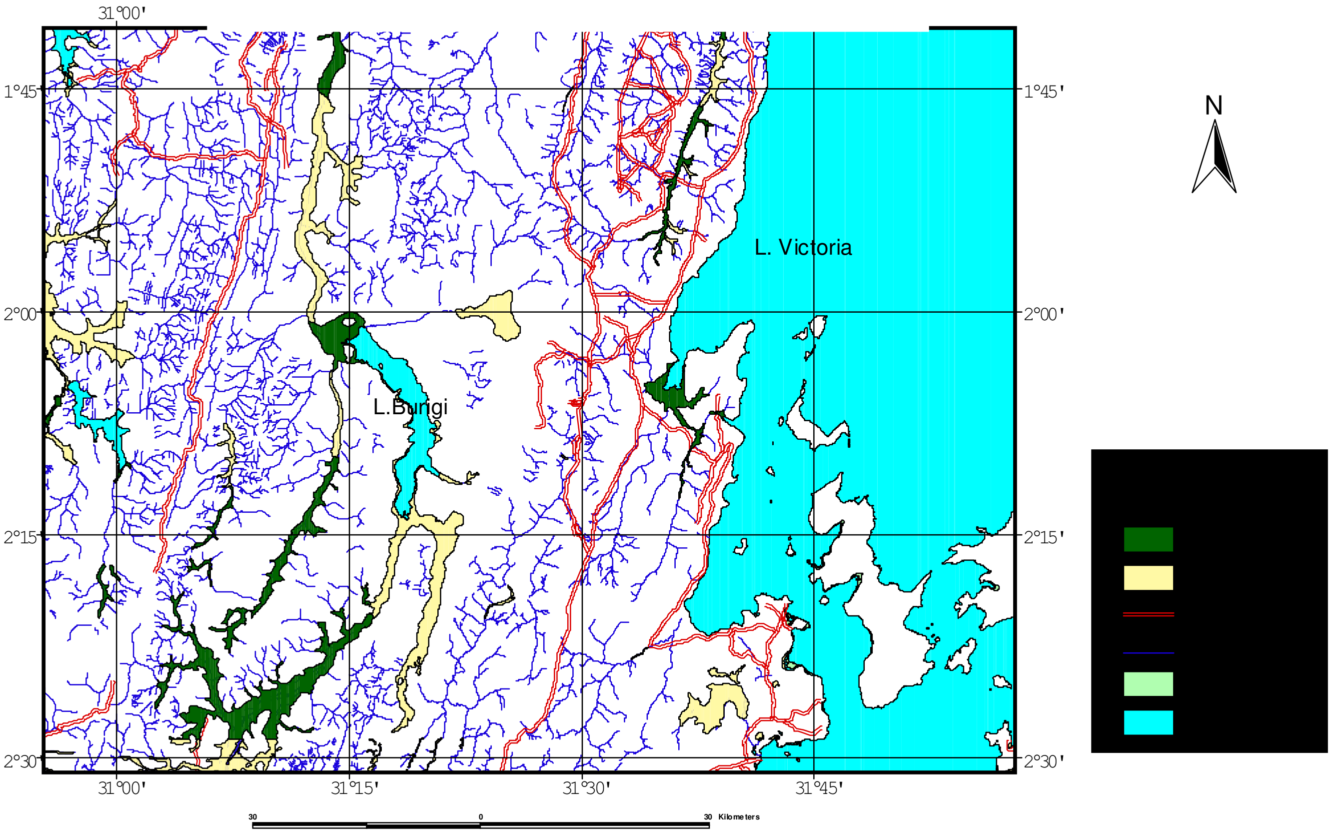

Figure 5: Drainage System Western Part of Lake Victoria