Seasonal Dynamics of The Phytoplankton Community in Relation to Environment in Lake Baringo, Kenya (Impact on the Lake's Resource Management)

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ABSTRACT

Studies were conducted in Lake Baringo between May 1994 and April 1995 to map temporal changes in productivity (phytoplankton standing stock) and attempt to relate these changes to environmental parameters in this ecosystem. Fourteen phytoplankton genera were recorded and described. Blue green algae (Cyanophyta) were the most dominant contributing 90.89% of the total biomass followed by green algae-Chlorophyta (9.08%) and finally by diatoms - Bacillariophyta (1.23%). Seasonal changes were observed for the three major plant nutrients. Soluble reactive phosphorous (PO_4-P) ranged from 3.75 to 112 µgP/l. Nitrate nitrogen (NO_3-N) ranged from 1- 110 µg N/l and finally the values for dissolved silica (SiO_2) ranged from 2.1 – 20.5 mg SiO_2/l. *Secchi* disc depth ranged from 0.04-0.06 m. The study further observed that phytoplankton productivity in this ecosystem is limited by the high level of suspended silt, except for the dominant phytoplankton *Microcystis aeruginosa* (Kutz.) Kutz., which regulates its buoyancy by forming vacuoles, while other algal species sink out of the euphotic zone. Results obtained in this study show that the lake is undergoing drastic eutrophication resulting in deterioration of the water quality, frequent algal blooms, decreased fish yields and subsequently reduced income to the local communities. The eutrophication of the lake is further aggravated by unchecked damming and diversion of rivers flowing into the lake coupled with long spells of drought being experienced in the area and an increasing human and livestock population.

Key Words: Phytoplankton, Nutrients, Water quality, Resources, Lake Baringo

INTRODUCTION

Water is an important basic resource for humanity. The availability and quality of this resource is however rapidly declining with burgeoning population.

The quality of water, especially of eutrophic waters is essentially determined by the quantity of algae. Drinking water supply, recreational activities and fisheries can be impaired by high phytoplankton biomass. Therefore, water quality management has to monitor the phytoplankton content in order for instance to come up with preventative measures such as aeration to prevent fish kills during the decay of the planktonic biomass (IMHOFF AND ALBERRECHT 1975).

Phytoplankton development in aquatic ecosystems is greatly enhanced by increased level of the major plant nutrients. This is because some of the nutrients are involved in the intercellular metabolic regulation and as building blocks in protein molecules (CRUL 1993). The major nutrients that regulate algal growth are soluble reactive phosphorous (SRP), nitrate nitrogen (NO_3-N) and dissolved silica (SiO_2). The silicates are a major constituent in the cell walls of the diatoms. Water temperature and turbidity are equally important for they have a direct bearing on the development and response of phytoplankton.

Previous documented studies on Lake Baringo include the work of BEADLE (1932) and PEIJER (1974). Associated work (KALLQUIST 1978) revealed that the phytoplankton of the lake is dominated by blue green algae *Microcystis aeruginosa* (Kutz.) Kutz. and to a less extent by *Anabaena circinalis* Rabh. ex Born. & Fl. In the recent past the lake has been besieged by a myriad of ecological disruptions including among others; decreased fish yields, siltation, deteriorating water quality, frequent algal blooms and increasing levels of poverty of the adjacent lake communities.

The aim of the present study was to document the temporal variation of the phytoplankton species composition and relate this to the environmental parameters.

MATERIALS AND METHODS

Study area

Lake Baringo (975 m above sea level), is the third largest Kenyan Rift Valley Lake after Lake Turkana and Lake Naivasha. The lake has a surface area of 129 km^2 and a mean depth of 5.25 ± 1.77 m (Fig. 1). A large proportion of the shoreline is regular apart from the northern part of the lake, which has deep bays and gulfs. River Molo and Ndau are the main rivers flowing into the lake from the south. Other smaller streams include the Perkera and Chemeron. There is no surface outflow from L. Baringo, however it has been documented that the lake has an underground outlet, which shows up at Kapedo on the Baringo-Turkana border. The water is alkaline because of the accumulation of the salts carried into the lake by surface runoff and from hot alkaline springs.

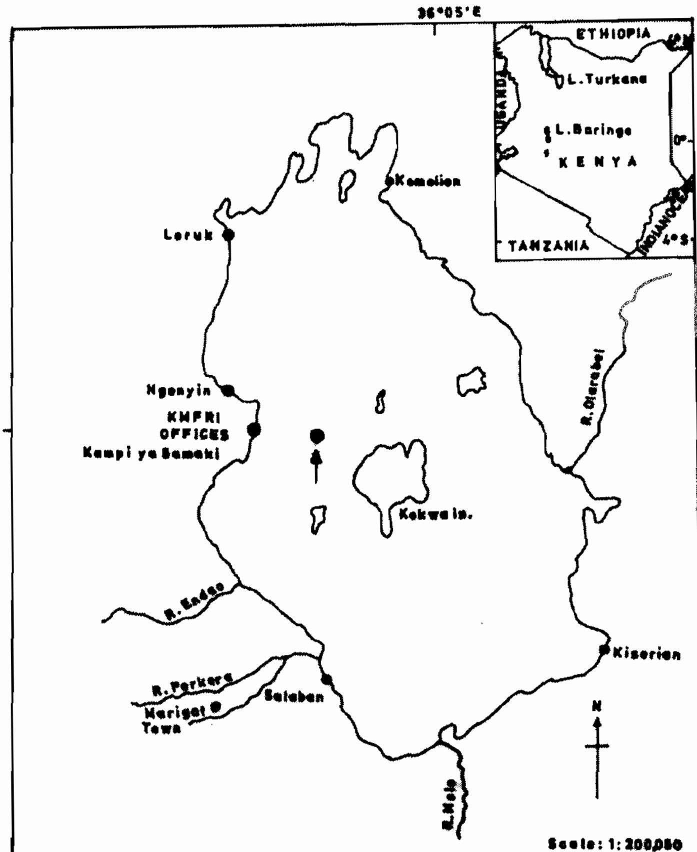

Fig 1: Map of L. Baringo showing the main influent rivers. Arrow indicates the fixed sampling station, which was occupied between May 1994 to April 1995.

The catchment area of the lake is 6820 km^2. It includes a large part of the western escarpment of the Rift Valley from where most of the water is derived from. The southern part of the drainage area consists of cultivated land

and patches of forest mainly on the escarpment. Part of the northern drainage is bushy interspersed with wooded grasslands, which is utilized for pasture for herds of goats and cattle. The grazing pressure on this arid land has led to severe soil erosion on the land adjacent to the lake.

Sampling for water and phytoplankton

Samples for water and phytoplankton were taken on a monthly basis from May 1994 to April 1995 at a fixed station (Fig. 1). Samples were taken between 09.00 am and 12 noon.

Light penetration was estimated with a 20-cm diameter, black and white *Secchi* disc. Turbidity was measured with a Hach Turbidimeter 2100P. Water temperature and dissolved oxygen were measured with a yellow Springs Instruments dissolved oxygen meter YSI 57. The pH was determined with a pH meter model 49 and Conductivity with a Microprocessor conductivity meter LF96.

Water samples were collected with a 3 litre Van Dorn sampler. A portion of the water samples (50 mls) were analyzed for total alkalinity and total hardness by titration with 0.02N HCl to a final pH of 4.5 using methyl indicator and with 0.02 N EDTA respectively as outlined in GEMS (1992). Spectrophotometric methods were employed to determine the soluble reactive phosphorous (SRP) and nitrate nitrogen as outlined by MACKERETH *et al.,* (1978) and silicates according to APHA (1985).

For phytoplankton analysis, 250 ml of the water was placed in a polyethylene bottle and fixed immediately with Lugols iodine solution. After 48 hours decantation, the lower layer (20-25 ml) containing the sedimented algae was put in a glass vial and stored in a dark cool box. The known volume of the concentrated sample was used for the identification and counting of the phytoplankton under an inverted microscope. Phytoplankton species were identified using the methods of HUBER –PESTALOZZI (1968) as well as some publications on East African lakes (see the references in the checklist of COCQUYT *et al.,* 1993).

Phytoplankton densities (individuals l^{-1}) were estimated by counting all the individuals whether these organisms were single cells, colonies or filaments.

RESULTS

Environmental factors

The most important meteorological conditions of this area are characterized by the alternation of two seasons: Dry season (September – February) and the rainy season (March – August) as shown in Fig. 2. The mean annual precipitation ranges from about 1500 mm on the western escarpment of the Rift Valley to about 600 mm on the eastern and southern zones of the lake. Marigat town received 645 mm on average per year in the period 1954 to 1970 (EAST AFRICAN METEOROLOGICAL DEPARTMENT 1975).

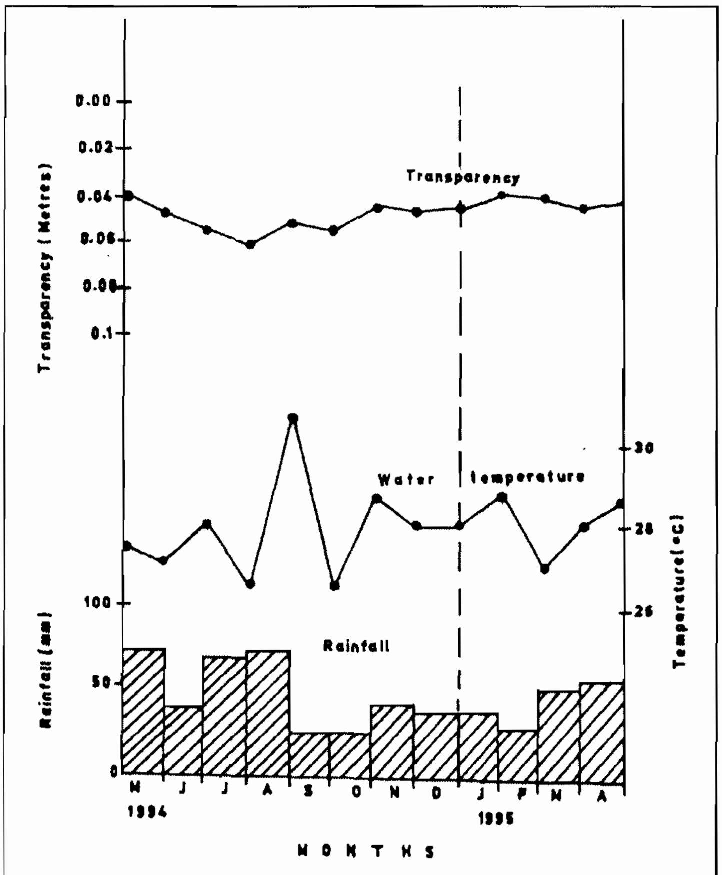

Fig. 2: Seasonal variation in the *Secchi* disk transparency, surface water temperature and rainfall at Lake Baringo during the sampling period. Data for rainfall was provided by Meteorological Department based at Marigat town.

Surface water temperature changed slightly throughout the year. The lowest values during the dry season were 26 and 26.9 °C. These values were recorded in the middle of the dry season. In the rainy season, values fluctuated between 26.5 – 33.0 °C (Fig. 2). This gives a seasonal fluctuation of around 7 °C. Values for pH were neutral to slightly alkaline (7.2 – 8.6) (Fig. 4a). The pH values however were uniform from surface to bottom,

possibly due to vertical mixing caused by strong winds, which normally occurred in the afternoon. Surface values of the total alkalinity fluctuated between 215 – 296.5 mg/l as $CaCO_3$ (Fig. 3a). These are quite high when compared with those of other African Lakes (TALLING 1965). *Secchi* disc visibility was very low throughout the sampling period and ranged from 0.04 – 0.06 m (4 - 6 cm) (Fig. 2) and was positively correlated to the density of *Microcystis aeruginosa*, which was the most predominant phytoplankton in the lake (Fig.6 b).

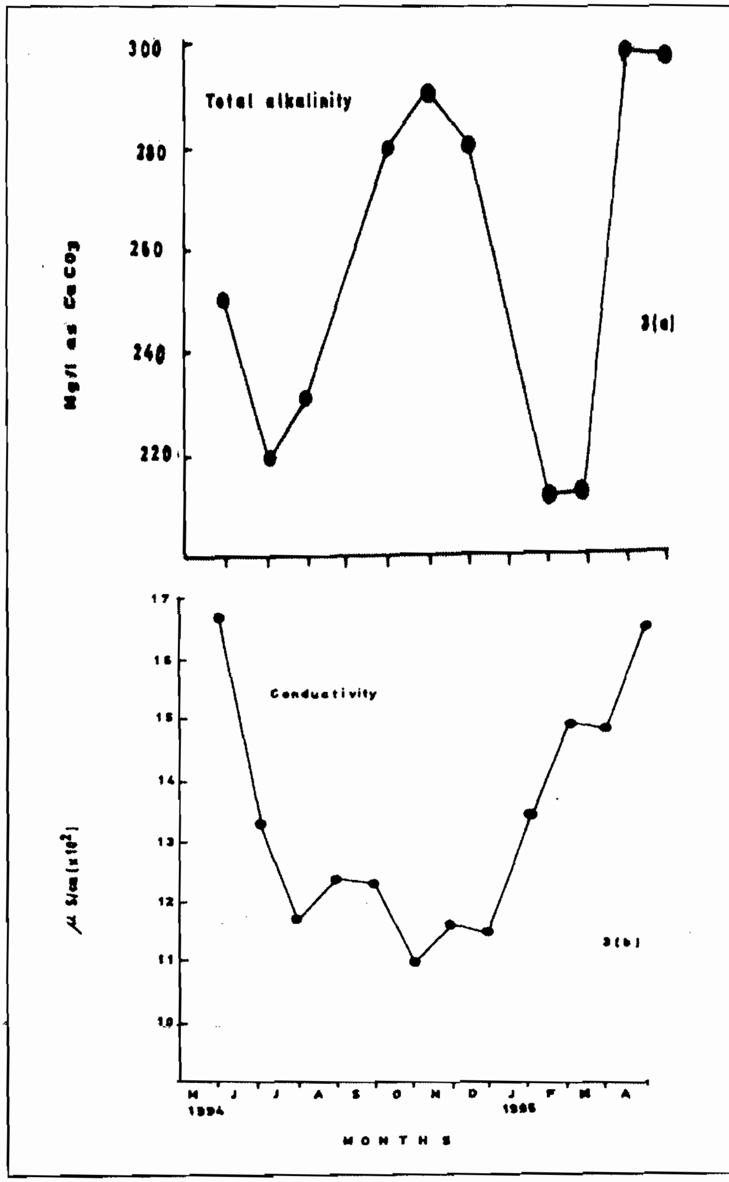

Fig 3a: Temporal variation in Total alkalinity at L. Baringo during the sampling period

Fig 3b: Temporal variation in Total Conductivity at L. Baringo during the sampling period

Conductivity and Total hardness ranged from 1140 – 1662 µS/cm and 33-45.2 mg/l as $CaCO_3$ respectively (Figs. 3b & 4b). Seasonal changes were observed in the three plant nutrients; PO_4-P, NO_3-N and silica (SiO_2) (Fig. 5). During the rainy season, the water contained larger amounts of the three nutrients than in the dry season, however, the PO_4-P and NO_3-N concentrations decreased considerably in June, July and August due to enhanced blooms of *Microcystis aeruginosa* and *Anabaena circinalis (*Figs. 5a + b*)*. The concentrations of dissolved silica were enhanced in most cases, in excess of 2 mg/l (Fig 5c). Elevated concentrations were observed at the water surface in May 1994 (21 mg/l) and in April 1995 (24 mg/l). This corresponded to high water inflow from the influent rivers.

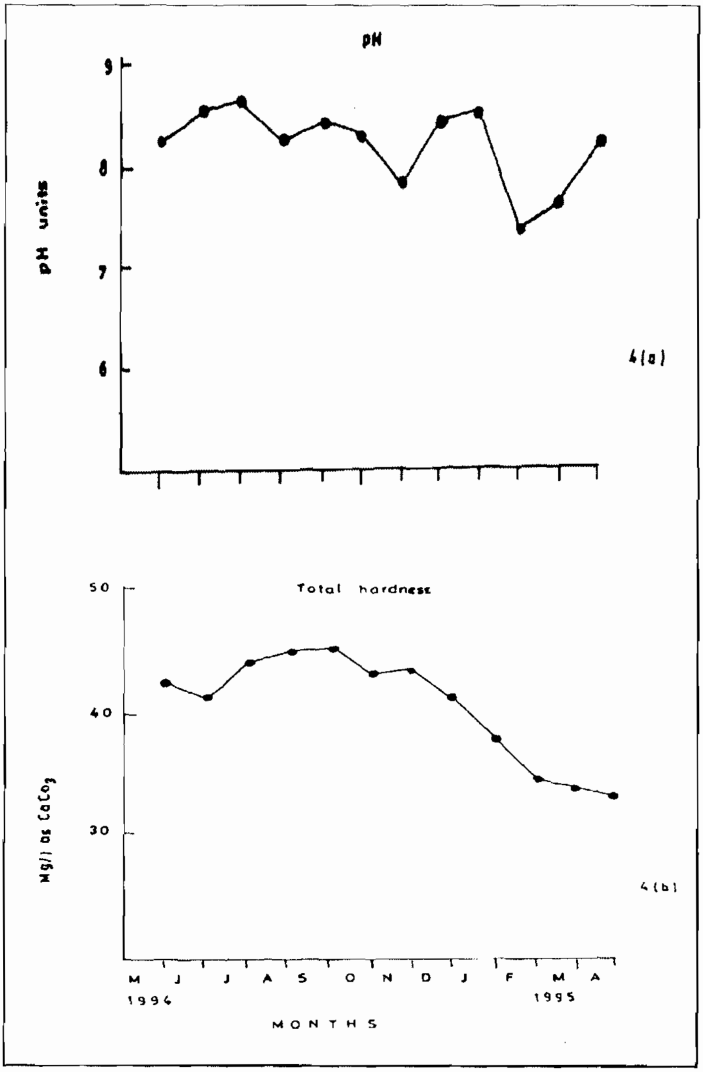

Fig. 4a: The evolution of pH at L. Baringo during the sampling period

Fig. 4b: The evolution of total hardness at L. Baringo during the sampling period

Phytoplankton

The phytoplankton was identified to genus level and to species level wherever possible. During the study, 14 genera were recorded and described. Table 1 displays the genera and their relative abundance (percentage of the sample in which the genus occurred).

Cyanophyta (Blue green algae)

Microcystis aeruginosa and *Anabaena circinalis* were the most common species identified. The abundance of the aforesaid species varied seasonally (Fig. 6) with the *Microcystis aeruginosa* dominating in all the water samples. Concentrations were low in the dry season (October to April) but gradually increased during the rainy season, which was observed in the period from May to August. The highest concentrations for *Anabaena circinalis* occurred from

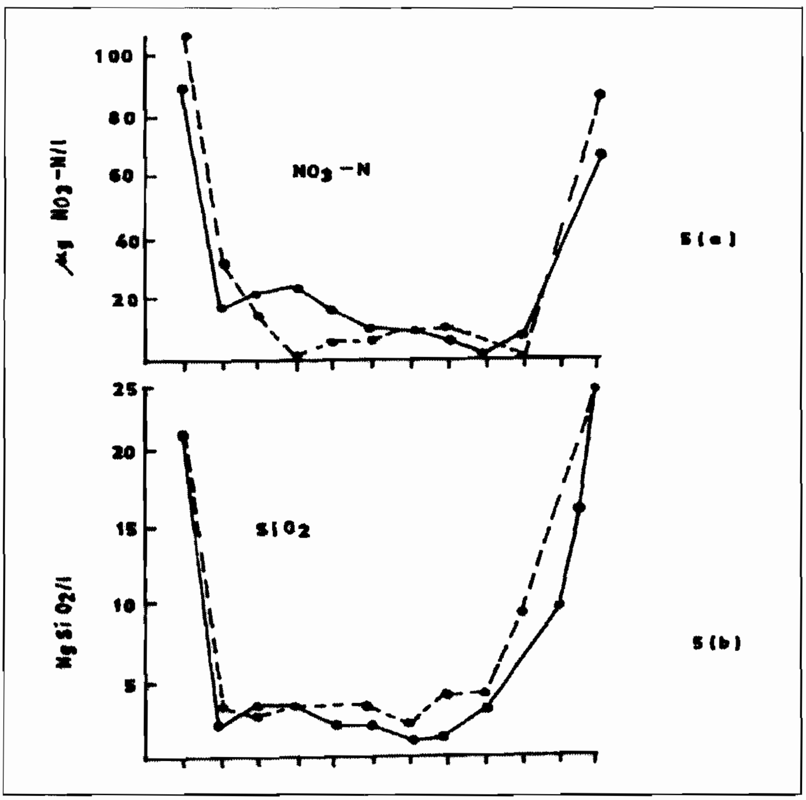

Fig. 5: Seasonal variation in Nitrate nitrogen (NO_3-N- µg N/l) (5a), Dissolved Silica (SiO_2 – mg SiO2/l) (5b) and Soluble reactive phosphorous (PO_4-P-µg P/l) (5c) for the surface and bottom samples

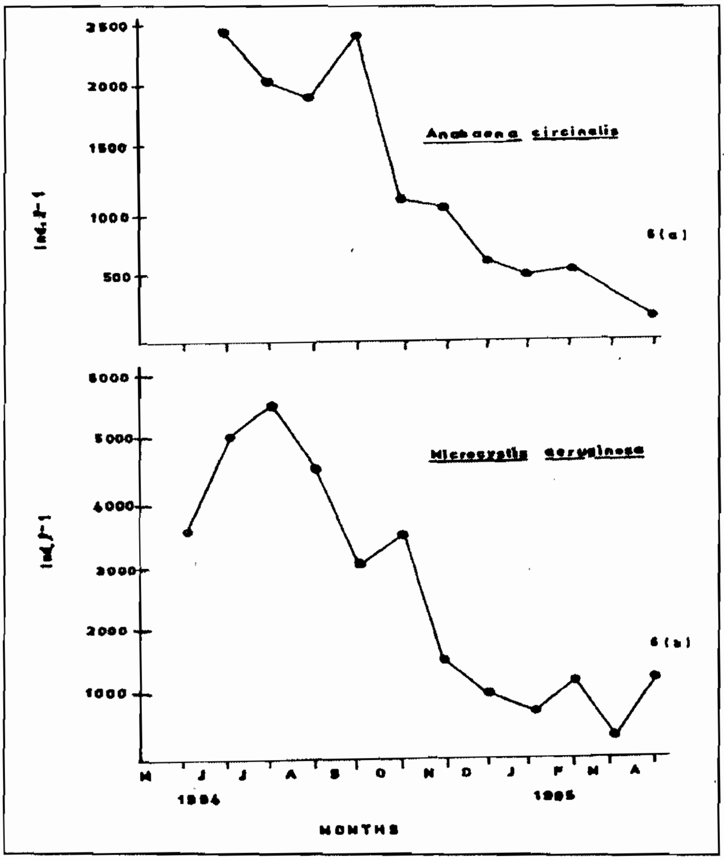

Fig. 6: Seasonal variation of the dominant Cyanophyceae; *Anabaena circinalis* (6a) and *Microcystis aeruginosa* (6b) at L. Baringo during the sampling period

Genus	Abundance
CYANOPHYTA	
Microcystis aeruginosa (Kutz.)Kutz.	****
Anabaena circinalis Rabh.ex Born. & Fl.	***
Merismopedia sp.	*
CHLOROPHYTA	
Pediastrum sp.	*
Oocystis sp.	*
Ankistrodesmus falcatus (Corda) Ralfs var.	***
falcatus	***
Cosmarium moniliforme (Turp.) Ralfs	**
Scenedesmus sp.	*
Chlorella sp.	***
Closterium sp.	
BACILLARIOPHYTA	
Aulacoseira agassizii (Ostenf.) Sim.	***
Cyclotella sp.	*
Rhizoselenia sp.	*
Unidentified pinnate diatom	***

Legend

****	Present in > 50% of the samples
***	Present in >30≤ 50% of samples
**	Present in >10≤ 30% of the samples
*	Present in ≤ 10% of the samples

Table 1: Phytoplankton genera recorded in Lake Baringo during the sampling period

June to September, closely following the trend observed for *Microcystis aeruginosa*. The two-phytoplankton species formed a considerable proportion in the diet of the tilapia sp. caught in the lake (NUGUTI pers. comm.).

Chlorophyta (green algae)

Regarding the green algae, the most important species encountered were *Cosmarium moniliforme, Closterium* sp., *Ankistrodesmus falcatus, Pediastrum* sp., *Oocystis* sp., *Scenedesmus* sp. and *Chlorella* sp. Large concentrations were recorded for *Cosmarium moniliforme* in November 1994 and even relatively high values ($9x10^4$ individuals l^{-1}) at 2 cm below the surface in December 1994 (Fig.7c). *Coelastrum* sp. counts were high from June to July 1994 and in March and April 1995. *Ankistrodesmus falcatus* concentrations were enhanced during the months of July 1994 and April 1995 (Fig. 7a).

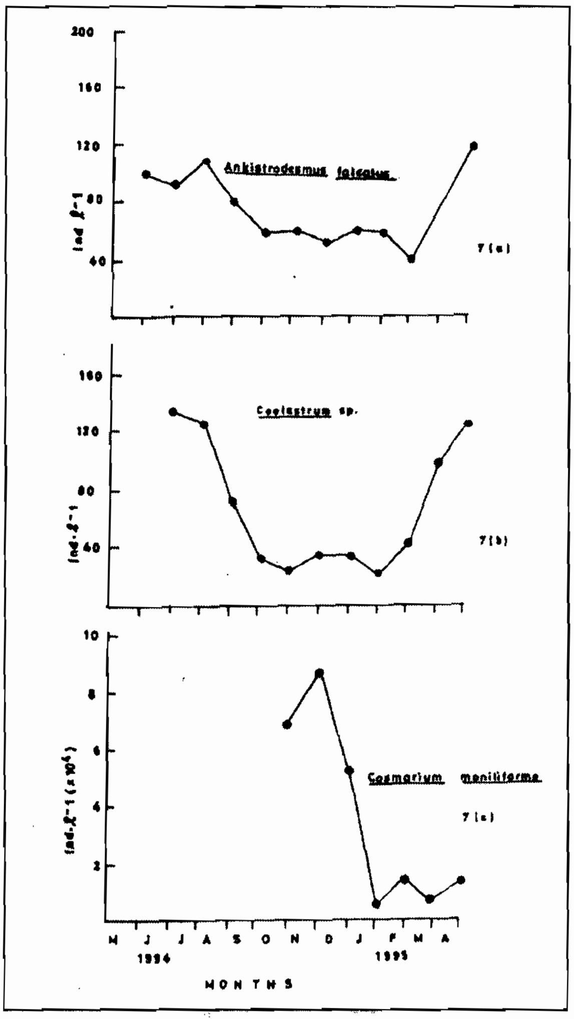

Fig.7: Seasonal variation of the dominant Chlorophyceae; *Akinstrodesmus falcatus* (7a) *Coelastrum* sp. (7b) and *Cosmarium moniliforme* (7c) at L. Baringo during the sampling period

Bacillariophyta (Diatoms)

In general, the diatoms (Bacillariophyta) concentrations were rather low all the year round. *Aulacoseira agassizii, Cyclotella* sp., *Rhizoselenia* sp. and unidentified pinnate diatom were the main genera identified in the samples. *Aulacoseira agassizii* was found in all samples but always in small numbers (concentrations< 300 individuals/l) (Fig. 8b). *Cyclotella* sp. was rare but was found abundantly in the month of February 1995 (Fig. 8a).

DISCUSSION

Dissolved NO_3-N and PO_4–P values (See Fig. 5a + c) obtained in this study were high compared to other East African lakes (TALLING 1965). According to (BONEY 1975) critical levels of dissolved silica (SiO_2) that would limit the growth of diatoms were estimated at 0.5 mg/l. In Lake Baringo, the lowest level of silica recorded was 2 mg/l (Fig. 5b). This shows that levels of dissolved silica are well above the values that might possibly limit diatom production in this ecosystem.

The lake has a large surface area 129 km² and a mean depth of 5 m, which together with high levels of dissolved nutrients, should support the growth of highly diversified and abundant algal population, especially diatoms due to the high silica content present. This is not the case since the frequent algal blooms that occur in the lake consist almost entirely of blue-green algae *Microcystis aeruginosa*. The predominance of *Microcystis aeruginosa* and the rareness of green algae and diatoms in the lake can only be explained by other factors other than nutrients, which were enhanced during the sampling period. We hypothesize that this

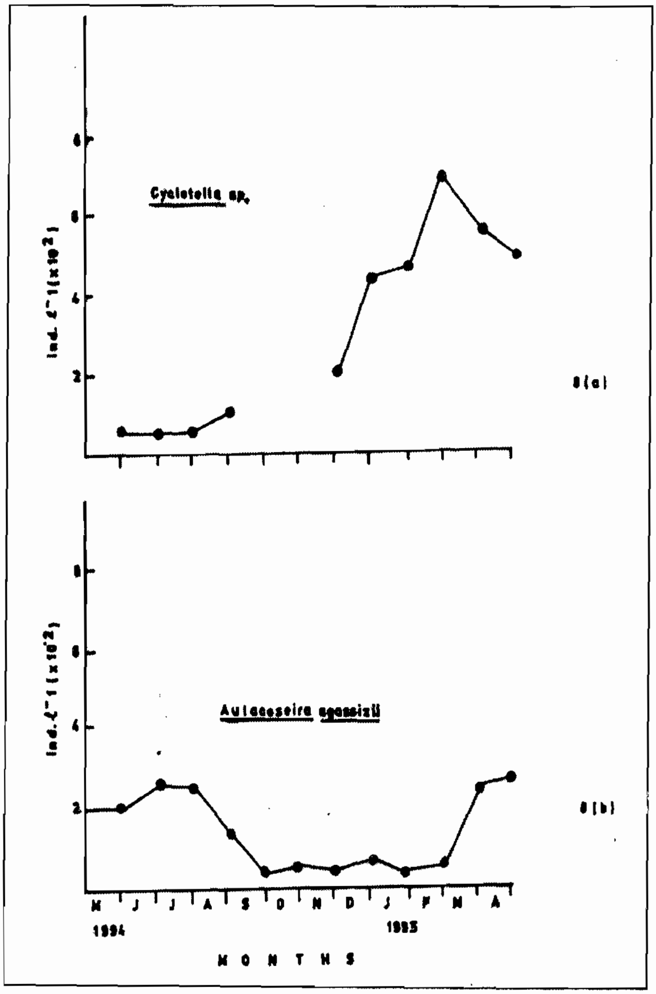

Fig. 8: Seasonal variation in the dominant Bacillariophyta; *Cyclotella* sp (8a) and *Aulacoseira agassizii* (8b) at L. Baringo during the sampling period

could be possibly due to a consequence of high silt content of the water that limits the light penetration. This is consistent with low values of the *Secchi* disc visibility observed in this study (Fig.2). Photosynthetic production is therefore possible only in a rather narrow zone near the surface. Under these conditions, it is crucial for the algae to accumulate in this zone.

Microcystis aeruginosa is able to regulate the buoyancy of its cells by forming vacuoles (KALLQUIST 1987), while most of the green algae and diatoms sink out of the trophogenic zone during the periods of calm weather (BINDLOSS *et al.*, 1970). *Microcystis aeruginosa* rise to the surface to capture more light for photosynthesis (DINSDALE AND WALBY 1972). This is an important property of *Microcystis aeruginosa* and is the reason for the development of the conspicuous green scum often seen on the surface of the lake. Some genera of green algae, for instance *Closterium* sp. and *Ankistrodesmus falcatus* and some diatoms take advantage of the buoyant *Microcystis aeruginosa* by attaching themselves on it thus maintaining themselves in the trophogenic zone.

Lake Baringo presently exhibits the traditional symptoms of eutrophication; abundant plant nutrients, low transparency, frequent algal blooms and with light as a limiting factor to primary production. This decline in the quality of the lake's water has a far-reaching consequence on the ecology of the lake and to about 300,000 people living around the lake. The most affected population is that of about 4000 inhabitants of Kampi ya Samaki town situated on the lakeshore who depend on the lake for their livelihood. According to the local communities, the "Lake is dying". In the three years preceding the study, the lake has receded by more than one kilometer leaving white rocks and sand behind (NUGUTI pers. comm.). Kampi ya Samaki was once a very important fishing outpost for the community that relied on fishing to feed, clothe and educate their families. This dry and remote town was for years a source of nourishment and income for many Kenyan families adjacent to the lake where poverty is endemic. The center grew into a major economic location with a co-operative society. This helped in providing fishing equipment, loans and in finding marketing outlets for the fishing community. During the peak fishing periods, a fisherman's average net income was always persistently higher than Ksh. 1000 per day. For the last three years preceding this study the fishing community of Kampi ya Samaki were migrating to other parts of the country. Indeed only a handful of the original 200 fishermen still linger on. Those remaining could barely feed their families as fish catches fell from about 240

metric tons in mid seventies to about 13.7 tons in 1995. With the collapse of the fishing industry, most of the other businesses also collapsed resulting to diversification of activities. The majority of the fishing boats have been converted to providing boat-rides to tourist for a fee. During the low tourist season the community would go for days without income and at such times, starvation would set in. The poverty situation is thus exacerbated.

The inhabitants do not practice any farming, as the area is extremely dry, the food is brought from Nakuru town, 120 km away and sold at high prices to the people who no longer have a regular source of income. Now with the "death" of the fishing industry and the eventual withdrawal of the fishing community from the lake, spells doom for the local community. While the community has no illusion about the centre rising again as a fishing outpost, they still need clean water for domestic consumption, however, the water continues to lose its potability for domestic and livestock use.

The results of this study indicate that the only way of increasing potential fish yield would be by reducing turbidity of the water which in turn would result in an increase in primary production of a variety of algal species. This study also links decrease in turbidity with the rise in lake water level. It was observed that transparency increased in the month of July 1994. This was the wettest month and the lake level rose by about 1.01 m. It is apparent therefore, that the settling out of silt is favoured by increased depth. Our findings are consistent with the results of KALLQUIST (1987), who also observed a decrease in turbidity with the rise in the level of water in Lake Baringo in 1977. She concluded that the settling of silt is favoured by increased depth. In recent years, the Lake Baringo catchment area has received below average rainfall, a factor that has contributed to the dwindling volume of lake water.

The inflow streams to the south of the lake contribute a large fraction of the water. River inflow is therefore one of the most critical factors influencing the lake because of its role in sedimentary and hydrodynamic processes, which in turn determine biotic characteristics of the lake. Apart from maintaining the higher lake levels, inflow streams are also important in moderation of hypersaline conditions developing during periods of low rainfall and high evaporation. Lake Baringo is also being increasingly denied an essential element of its natural cycle, namely the normal range of flooding event. The increasing impoundment of the inflow streams for domestic and agricultural use has a distinct effect on the lake. Molo River, the only permanent inlet has been dammed at Loboi where its waters are used for irrigation leaving only a

fraction of the river's waters flowing into the lake. Perkerra river, which passes through Marigat town, has its water diverted into horticulture plantations in the lower parts of Marigat town. Chemeron river has also been dammed for the construction of the Chemeron dam at Kipcherere. The dam's water is used in the lower areas of Marigat and Kimalel. The latest damming is on Endao River, which originates from Tugen hills. A multimillion dam (KIRDAM) intended to serve the whole of Kabarnet town and its environs is currently under construction near Kituro trading center. With all the above barriers and diversions of the lake's only inlets, coupled with high evaporation rate in this arid region and given that the lake has an underground outlet, a situation arises where the inlets are blocked and the outlet is open. Water is flowing out but none is flowing in, save from scarce rains. This explains why the lake has recently receded by more than one kilometer. Preliminary findings indicated that some of the lake's ichthyofauna may be adversely affected by changes in riverine water quality and quantity flowing into the lake as a result of dam construction. The fish, *Labeo cylindricus* (Peters) that once flourished, is on the brink of extinction in the lake. This is most likely due to interference with normal range of flood events that are important for successful breeding of this species. The African Carp *Barbus gregori* (Boulenger) may not be breeding successfully in the lake (NUGUTI pers. comm.)

Nutrients entering the lake are mainly burdens from non-point sources as there is little industrial development in the catchment area. The increase in dissolved nutrients occurs at the onset of rains and flooding in May-June. During this time the natural draw down areas are flooded and plant nutrients from grass and dung are rapidly released into the water. Due to population increase, the pastoral communities occupying the greater part of the catchment area have destroyed the vegetation cover. This has resulted in inappropriately controlled soil erosion.

CONCLUSIONS

Results of the present study showed that the productivity of Lake Baringo is limited by high level of suspended silt as opposed to nutrients. Results further revealed that the lake is undergoing drastic eutrophication which has resulted in deteriorating water quality, frequent algal blooms, decreased fish yields and consequently reduced income to local communities. The eutrophication of the lake is attributed to unchecked damming and diversion of rivers flowing into the lake, long spells of drought being experienced in the area and increasing human and livestock populations. This study further emphasizes the need to empower the local community in the management and conservation of the lake's resources with more

emphasis on diversification of income generating activities to include ecotourism among others.

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Freshwater Rotifera of the Genus *Lecane* of Small Water Bodies in Western Kenya

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ABSTRACT

Rotifers of the genus *Lecane* from six small water bodies in the Lake Victoria basin, Western Kenya, were investigated. Out of the 20 species recorded, 53.8% were cosmopolitan species while the rest were tropicopolitan. *Lecane bulla* was the most common, occuring in 83% of the stations sampled. The least common species were: *L. furcata, L. hastata, L. ludwigii, L. luna, L. lunaris, L. nana, L. pusilla, L. unguitata* and *L. unguilata* with each appearing in only one station. The greatest species diversity was observed at a roadside impoundment SW1, approximately 0.5 hectares in area, with 75% of the species recorded. This also happens to be the type locality of two other rotifers, *Brachionus africanus* and *Itura symmetrica* (SEGERS *et al.*, 1994).

Key Words: Small water bodies Rotifera of the genus *Lecane*

INTRODUCTION

Almost all small water bodies in Western Kenya are man-made formed mainly in excavation pits left behind during road constructions. They are small in size rarely exceeding one hectare in area. Majority of these impoundments may serve as water sources for the local communities and their livestock.

There is scarcity of information on zooplankton population structure of Lake Victoria and this is even more lacking in the small water body impoundments and littoral habitats in the basin. Apart from the earlier collections of WELTNER (1897), DADAY (1907) and DELACHAUX (1917), the only recent work on the Kenyan part of Lake Victoria is, probably, that of MAVUTI and LITTERICK (1991). A study on the small water bodies in the basin has been done by SEGERS *et al.*, (1994). Other studies in other parts of the country include those by De RIDDER (1987) and De SMET and BAFORT (1990).

The genus *Lecane* is known to constitute a group of mostly littoral dwelling organisms. It is one of the most species-rich genera of zooplankton with over

160 species (SEGERS, 1996). The biogeography of the genus have been studied in depth and the species distribution is well understood (SEGERS, 1996). The African taxa consist of 67 species with six endemics. The objective of the present paper is to give some information on the occurrence of *Lecane* species in small water bodies in Western Kenya.

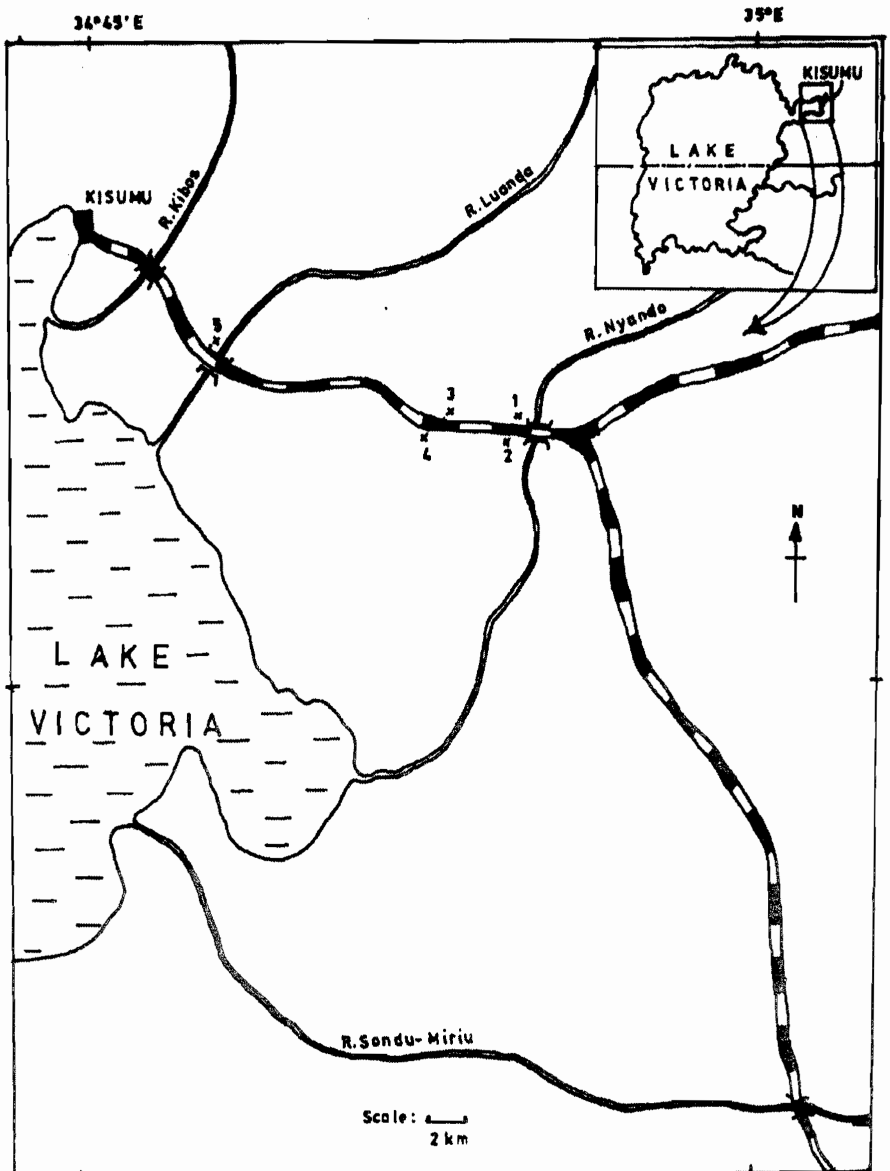

Fig.1. Map showing the position of some of the sampled water bodies, SW (1-5)

MATERIALS AND METHODS

Samples were collected from six impoundments in the Lake Victoria basin area. Five of these were roadside pools (Figure 1) while the sixth (SW6) was in Kakamega forest, approximately 100 km NW of Kisumu town. The roadside pools (Plate 1) had macrophytic growths with the common species being *Ipomea aquatica*, *Nymphae lotus*, *Phragmites australis*, *Typha domingesis* and *Ceratophyllum demersum*. The pond within the forest, however, had a dense mat of algae, *Nitella* sp.

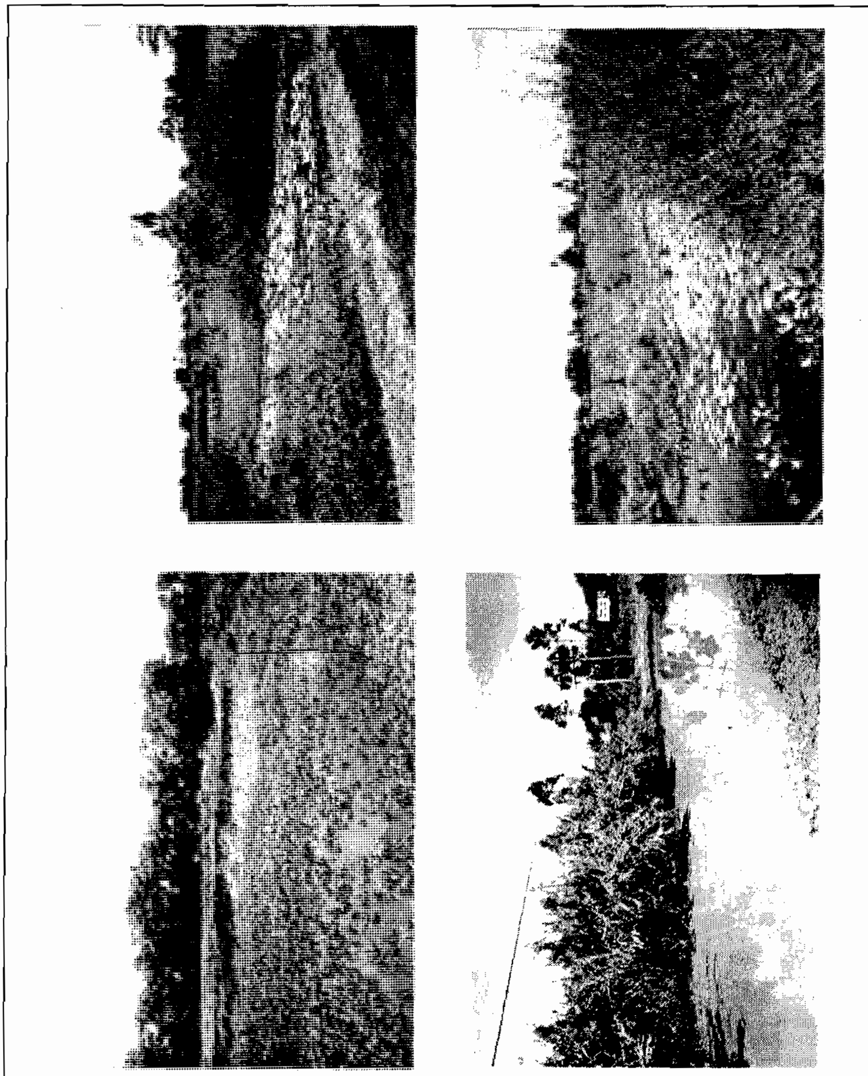

Plate 1. Photographs of some of the impoundments sampled

Samples were collected with a 50µm mesh plankton net and preserved in 5% formaldehyde solution. *Lecane* specimens were sorted under a Wild M10 dissection microscope (magnification X45) and picked with a fine glass capillary tube. Specimens were then transferred onto a slide with glycerine and examined under a Medilux 12 (Kyowa) compound microscope (magnification X1000). Drawings were made with the aid of a camera lucida and identification done using SEGERS (1995).

RESULTS AND DISCUSSION

Some physico-chemical characteristics of the sampling stations are given in Table 1.

Station	Coordinates	pH	DO (mg l^{-1})	Turbidity NTU	Conductivity µs cm^{-1}
SW1	00 10'23"S 34 54'26"E	6.36	4.8	24.4	240.0
SW2	Near SW1	8.19	14.4	24.2	159.3
SW3	00 10'06"S 34 53'42"E	6.42	8.0	43.0	151.0
SW4	00 09'57"S 34 51'53"E	6.11	8.0	33.7	262.0
SW5	00 08'41"S 34 48'34"E	6.20	9.6	11.4	182.5
SW6	-	6.00	14.4	19.7	121.0

Table 1. Some physico-chemical characteristics of the sampled stations

The occurrence of some *Lecane* species in the Kenyan waters has previously been reported by mainly De RIDDER (1987) and SEGERS *et al.*, (1994). The former reported on organisms from the Rift Valley and coastal regions while the latter gave an account of organisms from two small ponds, in the Lake Victoria basin, one of which happen to be a type locality for other rotifers *Brachionus africanus* and *Itura symmetrica* (SEGERS *et al.*, 1994). In the present study, 20 species of *Lecane* were reported from the six localities of which nine are new records for the Kenyan zooplankton (Table 2).

Organisms reported earlier but not recorded in this study are *L. aculeata* by NOGRADY (1983), *L. glypta, L. hornemmani* and *L. inermis* by De RIDDER (1987). De SMET and BAFORT (1990) found *L. arcuata* in the mount Kenya

	SW1	SW2	SW3	SW4	SW5	SW6
Lecane arcula Harring, 1914*	+		+			
Lecane bifurca (Bryce, 1892)*				+		
Lecane bulla Gosse, 1851	+		+	+	+	+
Lecane closterocerca (Schmarda, 1859)	+					
Lecane furcata (Murray, 1913)*	+					
Lecane hamata (Stokes,1896)	+		+			
Lecane hastata (Murray, 1913)*	+					
Lecane inopinata Harring & Myers,1926*	+		+			
Lecane leontina (Turner, 1892)				+	+	
Lecane ludwigii (Eckstein, 1883)*	+					
Lecane luna (O.F. Muller, 1776)	+					
Lecane lunaris (Ehrenberg,1832)	+					
Lecane nana (Murray, 1913)*	+					
Lecane papuana (Murray,1913)	+		+		+	+
Lecane pusilla Harring, 1914	+					
Lecane pyriformis (Daday,1905)	+					+
Lecane quadridentata (Ehrenberg, 1832)*	+				+	
Lecane undulata Hauer, 1938						+
Lecane unguitata (Fadeev, 1925)*					+	
Lecane ungulata (Gosse, 1837)		+				
Total number of species	15	1	5	3	5	4

Table 2: The distribution of *Lecane* species in the six localities sampled
(* indicates new records for Kenya)

region. Others are *L. braumi, L. curvicornis, L. monostyla, L. tenuiseta and L. thienemanni* (MASAI unpublished). Figure 2 shows illustrations of some of the new species recorded in Kenya.

Station SW1 had the highest number of species while SW2 (paddy field) had the least. The former is the most permanent of the water bodies and second largest to SW5 in size. It also had plenty of aquatic plants including: *Ipomea*

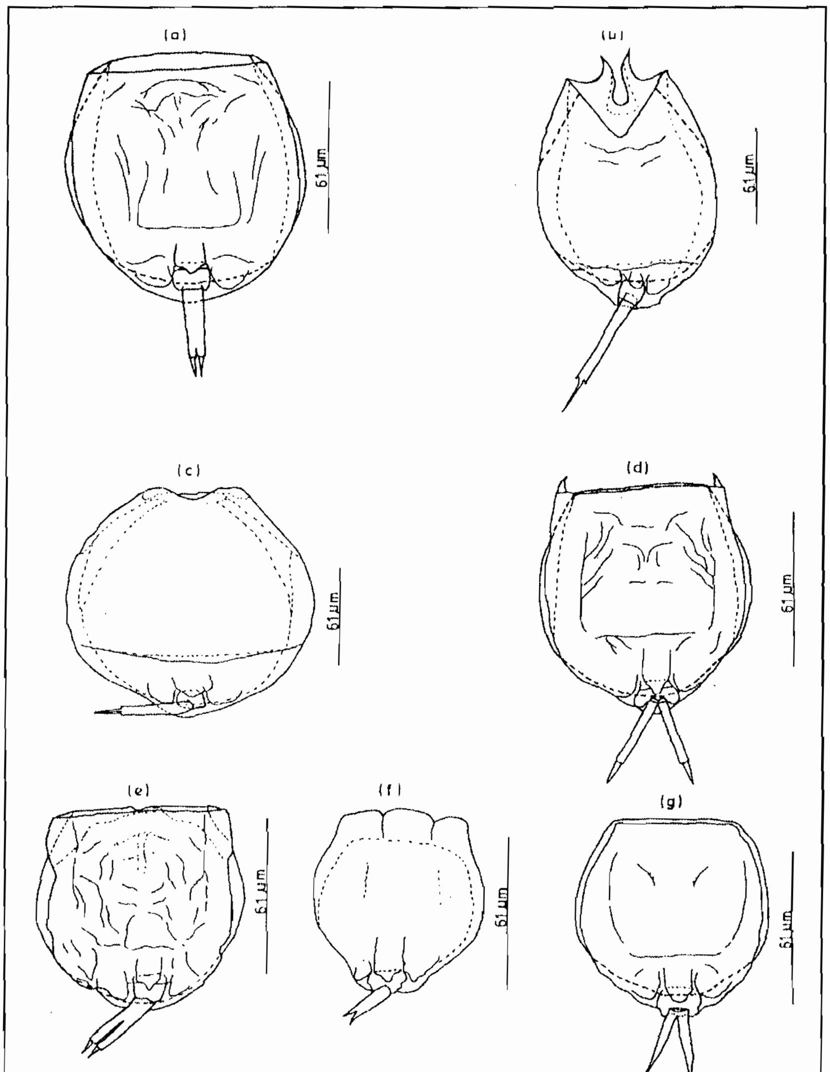

Fig 2. Some Lucane species newly recorded in Kenya waters (a) *L. furcata* (b) *L. quadridentata* (c) *L. unguitatata* (d) *L. arcula* (e) *L. inopimata* (f) *L. bifurca* (g) *L. nana*

aquatica, Ludwigia stolonifera and *Ceratophyllum demersum* among others which explains why it had the highest number of species. Station SW2, which is a paddy field, is the least stable since it is temporary and shallow (approximately 15 cm). Although SW5 is larger than SW1, it had fewer species since it has fewer aquatic plants, which is favorable for *Lecane*. It, however, had some grasses on the banks and some *Nymphae lotus*, *Ludwigia stolonifera* in its shallow areas. The results show that fish predation does not affect the occurrence of *Lecane* since it is in the impoundment with the highest species diversity which had most fishes.

Small water bodies in the Lake Victoria basin can be used as refugia for certain endangered fish species e.g. haplochromines. In such habitats, such species would be separated from predators and competitors in the lake. The habitats could also be utilized for limnological and ecological studies since variables could easily be controlled. Naturally, before such activities are undertaken it would be important to know the organisms occurring in the systems after which the effect of any variable would easily be quantified. These habitats have not been studied much and some organisms may have been lost, before being recorded, due to human activities mainly through pollution. There is need to conserve and intensify studies on these habitats.

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A Study of *Hydrocynus vittatus*, Castelnau in Lake Kariba, Zimbabwe

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ABSTRACT

The growth and mortality of tigerfish (*Hydrocynus vittatus* Castelnau) from the Bumi Basin of Lake Kariba and the Ume River were studied. Estimates of asymptotic length (L_8) and growth constant (k) obtained using ELEFAN (Electronic Length Frequency Analysis) were 63.9 cm and 0.32 per year, respectively. Growth performance index (Ø') was 3.11. These values were compared with those obtained by other workers. Natural and total mortality were 0.66 and 0.995, respectively. Fishing mortality and exploitation rate were 0.335 and 0.337, respectively. Catches and catch per unit of effort (cpue) were higher in the riverine than in the lacustrine sites. There were marked differences in size structure between riverine and lacustrine sites.

INTRODUCTION

Lake Kariba supports a thriving fishery that has three distinct sectors; the artisanal gillnet fishery, the recreational (sport) fishery and the Kapenta fishery. The artisanal fishers rely on gillnets to exploit species in the littoral zone. The total annual catch from this fishery on the Zimbabwean side was about 1 281 metric tonnes in 1993 (SANYANGA and MUCHABAIWA, 1994). Tigerfish (*Hydrocynus vittatus* Castelnau) made up 22% by weight of the total annual catch.

In the Kapenta fishery, the target species is the 'sardine' *Limnothrissa miodon* (Boulenger). This small clupeid inhabits the *pelagic* areas of the lake. The total annual catch for 1993 was about 19 960 tonnes. Several species are harvested as by-catch in this fishery, of which *Hydrocynus_vittatus* is the dominant species. The *H. vittatus* by-catch for 1993 was about 10 tonnes or 42% by weight of the total annual by-catch.

Sport (recreational) fishing is popular on Lake Kariba. The dominant fishing gear among the anglers is rod and line. Tigerfish is a popular angling species. The annual Kariba International Tigerfish Tournament is very important.

Catches at this tournament can be as high as 4 metric tonnes.

H. vittatus is an important species in all three sectors of the fishery. Objectives of this study were; (a) to obtain estimates of several biological parameters, (b) to assess spatial and temporal variations in catches of *H. vittatus*.

Study Area

Lake Kariba is a manmade tropical reservoir built in 1958 to provide hydroelectric power to Zambia and Zimbabwe. It is located between latitudes 16^0 28' South and 18^0 04' South, and longitudes 26^0 42' East and 29^0 03' East. It has a mean length of 240 kilometres, a mean width of 40 kilometres and a mean depth of 29 metres. There are five distinct hydrological basins (Figure 1), which show a gradual change in hydrology from west to east. Basin 1 being the most riverine, Basin 5 the most lacustrine.

MATERIALS AND METHODS

Monthly sampling was conducted from May 1988 to December 1988. In 1989, sampling was undertaken in May, June, July, August, October and November. Multifilament gillnets with stretched mesh sizes of; 54, 70, 76, 89, 102 and 127 millimetres were used. Each gillnet was 45 metres long when mounted. The 70 mm net was used from November 1988 to June 1989; in all other months it was replaced by a 76 mm net. Nets were set between 1600 hours and 1800 hours in the evening and were lifted between 0600 hours and 0730 hours the next morning. Each station was sampled twice in each month. For each individual fish, the following parameters were recorded; total length (TL), standard length (SL), wet weight, sex and gonad (maturity) stage.

The current study was carried out in Basin 4 (Bumi Basin). There were five sampling stations: two stations were located on the Ume River (Tiger Bay and Shenga), the other three (Musamba, Bumi and Karonga) were in the littoral zone of the lake.

Electrical conductivity was measured in the surface water using a conductivity meter (WTW LF 91).

The Wetherall method in ELEFAN (GAYANILO *et al.*, 1989) was used to obtain a preliminary estimate of asymptotic Length (L_8) and Z/K. Total mortality (Z) was estimated using the Length-Converted Catch Curve routine in LFSA (SPARRE 1989). The final estimate of asymptotic length was then obtained from the Response Surface Analysis in ELEFAN. Natural mortality was estimated using Pauly's empirical formula. The mean annual temperature used was 26^0 C. Growth parameters were used to estimate the performance index Ø' (PAULY and MUNRO, 1984).

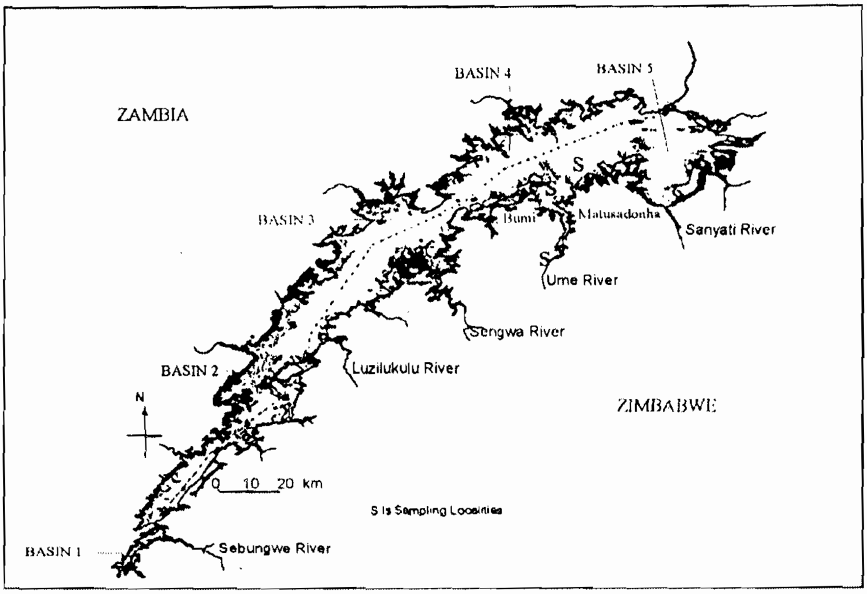

Figure 1: Map of Lake Kariba showing sampling localities

Statistical Analysis

Nested Analysis of variance (ANOVA) (SOKAL and ROHLF, 1981) was used to determine whether Catch per Unit of Effort (CPUE) and conductivity were significantly different between the lacustrine and riverine stations. The data were "normalized" using the logarithmic transformation.

Results

Table 1 shows the mean conductivity measured at each site. Asymptotic length (L_8) from Wetherall's plot was 62.12 centimetres, while Z/K was 1.798. The

final estimates of asymptotic length (L_8) from the Response surface Analysis was 63.9 cm, while the growth constant (K) was 0.318. Natural mortality (M) and Total mortality (Z) were 0.66 and 0.995 respectively. Fishing mortality (F) was 0. 335. The exploitation rate (F/Z) was 0.337.

Site	Musamba	Bumi	Karonga	Shenga	Tiger Bay
Conductivity (μ S/cm)	111.6	111.6	109.9	119.3	126
Standard Deviation	3.62	3.8	4.67	7.76	15.27
Sample size	25	26	26	26	26
	lacustrine	lacustrine	lacustrine	riverine	riverine

Table 1: Mean conductivity at the five sampling sites

Table 2 is a comparison of the growth parameters obtained in this study with those of other workers. Mean standard length of tigerfish in the different gillnets is shown in Table 3.

Total length to standard length ratio was 1.29 (n = 1244).
The length-weight relationship was of the form:

	This study	Anon 1993	Langerman 1984	Karenge 1992	Mudenda 1989	Beattie 1982
L_8	63.9	62	64.68	57.8	74	58.4
K	0.318	0.338	0.369	0.33	0.3	0.37
(Ø')	3.11	3.11	3.19	3.04	3.22	3.10
Basin	4	5	3	5	2	2

Table 2: Comparison of growth parameters (L_8, K and (Ø')) of *H. vittatus* from studies on Lake Kariba

$$\mathbf{W = 0.012 * SL^{3.12}} \quad (r^2 = 0.98;\ n = 1804).$$

Where:

W = wet weight (grams) SL = Standard Length (CM)

The linear relationship between total length (TL) and standard length (SL) can be expressed by the following linear regression;

$$\mathbf{TL = 2.7487 + 1.192SL} \ (r^2 = 0.98;\ n = 1244).$$

The ratio of males to females (as a percentage) was 53% to 47%. The mean

Mesh size (mm)	54	70	76	89	102	127
Length (cm)	23.6	30.2	31.2	37.5	43.9	48.3
Std. Deviation	4.3	5.5	6.2	7.6	8.0	6.3
% of Catch	63.9	9.9	11.6	7.5	3.4	3.7

Table 3: Mean Standard Length of *H. vittatus* caught in the different gillnet mesh sizes

length at which 50% of the fish were sexually mature was 27.5 cm for the males and 39.8 cm for the females. Mean catch per unit effort at the sampling sites is shown in Figure 2.

Catch per unit effort for Musamba and Tiger Bay during different months is shown in Figure 3, while Figure 4 shows the length frequency distributions at Tiger Bay, Shenga, Musamba and Bumi.

Results of the Analysis of Variance showed that catch per unit of effort (cpue) was significantly different between the lacustrine and riverine sites ($p<0.09$). Mean conductivity was also significantly different between the lacustrine and riverine sites ($p<0.02$).

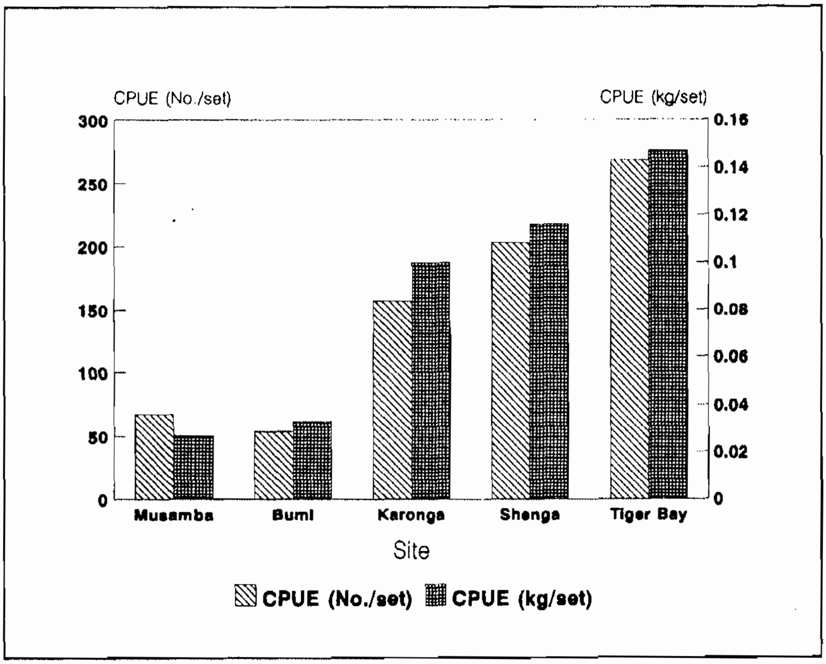

Figure 2: Mean catch per unit effort (CPUE) at the five sites

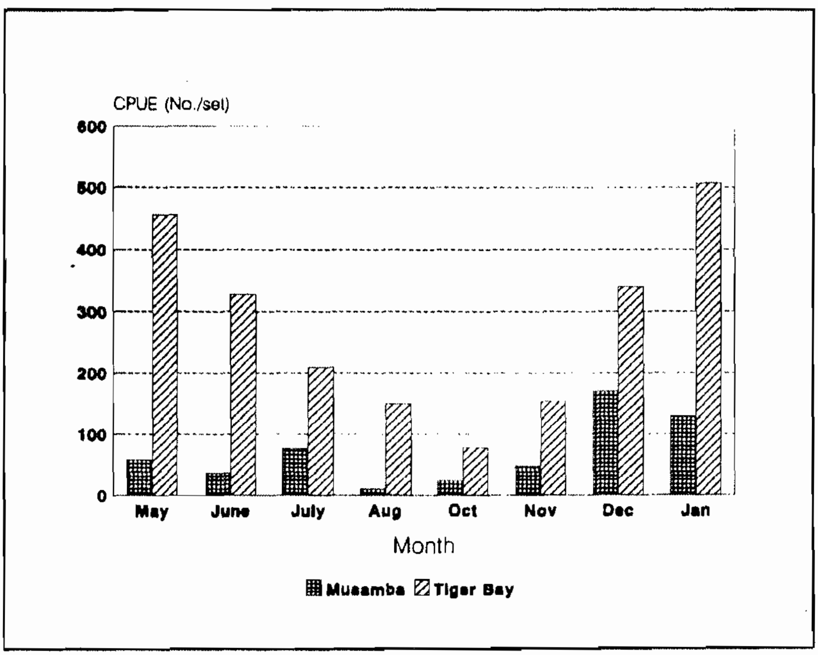

Figure 3: Catch per unit effort at Musamba and Tiger Bay sampling stations

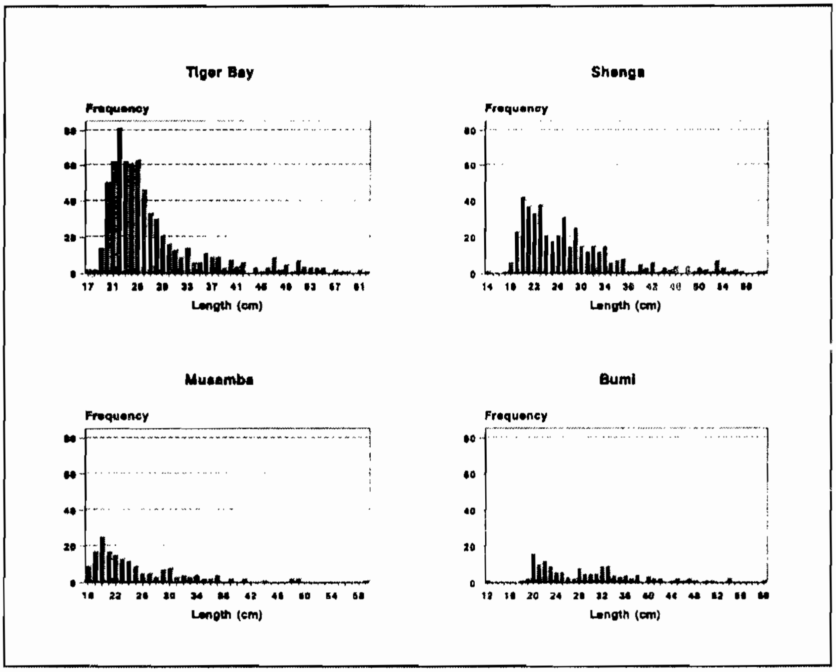

Figure 4: Length frequency distribution (size structure) at four sampling sites

DISCUSSION

The asymptotic length and growth constant obtained in this study were different from those obtained by other workers (Table 2). These differences are likely to be due to spatial variations since most of the studies were carried out in different areas of the lake. Another factor is that with length-based methods, the estimated asymptotic length is dependent on the largest size of fish caught. Thus, where large (older) fish are not caught, the asymptotic length will be smaller. This result shows that for a highly migratory species such as *H. vittatus*, length based estimates need to be validated using age-based methods.

Fishing mortality was low because three (Tiger Bay, Shenga and Karonga) of the five sampling sites were in an area closed to commercial fishing. Consequently, the exploitation rate (F/Z) was also low. MUDENDA (1989) noted that in the Sinazongwe area on the Zambian side, F/Z was 0.571. The

difference in exploitation rate between the Zambian and Zimbabwean side was due to two main factors. First, on the Zambian side, commercial fishing is carried out along the whole shoreline, while on the Zimbabwean side some areas are closed to commercial fishing. This means that there are fewer fishers and therefore lower fishing effort on the Zimbabwean side. Consequently, fishing mortality (F) is higher on the Zambian shoreline. Mesh size regulations also differ between the two sides. Minimum gillnet mesh sizes are 102 millimetres in Zimbabwe and 76 millimetres in Zambia. This results in fish recruiting into the fishery at a younger age (length at first capture see Table 3) on the Zambian side. Thus, *H. vittatus* are harvested more intensively on the Zambian side, hence the high exploitation rate.

The value of the growth performance index observed in this study was similar to that computed using data from Anon (1993), but differed with that from the other workers (Table2). The differences in Ø' values are likely to be due to temporal variation.

Given that the mean length at which 50% of the fish were sexually mature ($L_{mat50\%}$) was 27.5 cm and 39.8 cm for the males and females respectively, it can be noted that the tigerfish can spawn several times before they recruit into the gillnet fishery. Jackson (cited in KENMUIR 1973) observed that the breeding size of female tigerfish in Lake Kariba was 35 cm. The estimate of $L_{mat50\%}$ may be slightly high because the 114-mm mesh gillnet was not used and hence some of the sexually mature fish may not have been caught.

When the value of b in the length-weight relationship equation is greater than 3, weight growth is positively allometric (PAULY, 1984). TORRES (1992) reported a Total Length: Standard length ratio of 1.247, while the observed ration in this study was 1.29. The observed difference is likely to be a result of differences in sample size.

There were more males than females (1.12:1). LANGERMAN (1984) made similar observations in the Mwenda area of Lake Kariba (Basin 3). KENMUIR (1973) observed a higher proportion of females than males in the Sanyati area (Basin 5).

Conductivity has been used as an indicator of biological productivity. In the Morpho-edaphic index (MEI), conductivity is used to estimate fish production

(RYDER *et al.,* 1974). In the current study, conductivity was significantly different between the lacustrine and riverine sites ($p<0.02$). Thus the riverine sites have higher biological productivity as shown by the cpue (Figure 2). Thus, the nutrients from the catchment area have a significant impact on the productivity of the fishery. The low cpue observed in the lacustrine sites was also due to fishing since these two sites were in a commercial fishing area.

Figure 2 shows that *H. vittatus* was three times more abundant in the riverine sites than in the lacustrine. The cpue at Tiger Bay was low in the period from July to November, and it rose significantly during December, January and May (Figure 3). The high cpue at this site in the latter months was due to fish congregating in the river during the breeding season. *H. vittatus* is potamodromous and its breeding season extends from October to March (KENMUIR, 1973).

Most of the fish were caught in the 54mm mesh net (Table 3). These fish were caught mainly in the riverine sites. A marked difference was observed in the size structure in fished lacustrine sites and unfished riverine sites (Figure 4). Young fish dominated catches from the riverine sites with standard lengths between 18 and 30 cm. Angling is likely to have contributed to the low numbers of fish in this size category in the fished areas. Fishers in the villages (mainly women and children) fish regularly with rod and line. The fish caught in this way are mainly for domestic consumption. The other factor is likely to have been the dispersal of adult tigerfish mainly in the littoral zone of the lake.

SUMMARY

The growth of *H. vittatus* from the Bumi area was allometric. The following estimates were obtained; $L_8 = 63.9$ cm, $k = 0.318$ yr^{-1}, $Ø' = 3.11$. It was observed that estimates of asymptotic were influenced by spatial variations. Therefore, where data on absolute age are required, length-based estimates should be validated by other methods such as the use of scales or otoliths. Fishing mortality was low because some areas are not fished commercially. Electrical conductivity was significantly higher in the riverine sites than in the lacustrine sites ($p<0.02$). Riverine sites were also biologically more productive than the lacustrine sites.

Cpue data show that *H. vittatus* was more abundant in the riverine sites than in the lacustrine sites ($p<0.09$). Among the riverine sites, there was high variation

in abundance, an indication that the spatial distribution of *H. vittatus* was heterogeneous.

There were more males than females. Comparison with data from other workers showed that the sex ratios vary from one area to another. Populations (size) structures were markedly different between the unfished riverine sites and the fished lacustrine sites. Riverine sites had higher frequencies of the smaller length classes.

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Breeding Seasonality in the African Cyprinid *Barbus neumayeri*

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Key Words: Cyprinidae, Uganda, seasonal reproduction, hypoxia, gonadosomatic index

ABSTRACT

The seasonal reproductive cycle of *Barbus neumayeri* from a small intermittent stream in western Uganda was examined over a 1-yr period. Dissolved oxygen and water flow changed markedly over the year in the stream and were correlated with seasonal changes in rainfall. Gonad maturity and gonadosomatic index data indicated that *B. neumayeri* reproduced throughout the year but with peaks in reproductive effort in the wet season when oxygen levels were relatively high. Young juveniles were present throughout the year, but with recruitment peaks. Potential benefits of seasonal peaks of reproduction and recruitment include high oxygen levels, increased availability of habitat, and less competition among juveniles for food and other resources.

INTRODUCTION

In many tropical systems, fluctuations in rainfall represent the strongest seasonal change and affect the temporal and spatial variability of the environment for aquatic organisms. In floodplain rivers like the Amazon, huge areas of forest and savanna become flooded during the wet season and produce new seasonally available habitat (LOWE-MCCONNELL, 1964, 1975; WELCOMME, 1979; GOULDING, 1980). In smaller intermittent streams, habitats may change from fast flowing well-oxygenated waters in the wet season to small, stagnant,

hypoxic pools in the dry season (CHAPMAN and KRAMER, 1991).

Seasonal patterns of food, habitat availability, and water quality should be reflected in seasonal patterns of reproduction in fishes inhabiting these systems. Flooded wetlands and forests provide cover for developing young. In addition, the increased availability of habitat minimizes competition for food and other resources. Finally, hypoxia (oxygen scarcity) is widespread in tropical freshwaters, particularly in stagnant pools and swamps during the dry season. Many tropical freshwater fishes in seasonal rivers, streams, and swamps produce young at the onset of the rains when oxygen levels are higher, and conditions for growth and survival are optimal (LOWE-MCCONNELL, 1964, 1975, 1979; WELCOMME, 1979). However, within seasonal habitats, there is often variation among species from continuous breeders, to those exhibiting seasonal peaks in reproductive activity, to those highly seasonal breeders that exhibit well defined spawning periods (LOWE-MCCONNELL, 1979). Even among some closely related species within the same habitat, reproductive strategies may vary. For example, studies in Sri Lanka on six indigenous *Barbus* species from two river systems demonstrated reproductive spawning peaks that coincided with seasonal peaks in three species, whereas in the other three species spawning appeared to take place uniformly through the year (DE SILVA *et al.*, 1985).

Within Africa, the genus *Barbus* is widespread and occupies a range of habitats from fast flowing rivers to highly seasonal swamps. There is a range of reproductive strategies including dry season spawning, a breeding season coinciding with the rains, and continuous spawning (WHITEHEAD, 1959; WELCOMME, 1969; LOISELLE and WELCOMME, 1971; PAYNE, 1975; GAIGHER, 1976). In this study, aspects of the reproductive biology of *Barbus neumayeri* Fischer 1884 in a small forest stream in Kibale National Park, Uganda were examined. Monthly changes in the gonadosomatic index, maturity state, and size frequency distributions were quantified to detect seasonal patterns of reproduction and recruitment. Observed patterns were related to seasonal changes in rainfall.

METHODS

The study site was located in Kibale National Park in western Uganda (0°13' - 0°'41'N and 30°19' - 30°32'E), a mosaic of moist-evergreen tropical forest, swamp, grassland, exotic pine plantations, and colonizing forest. Two major river systems drain Kibale National Park: the Dura and Mpanga Rivers. Both

of these rivers consist of large permanent channels which flow freely for stretches but are choked by papyrus in deeper valleys for hundreds of metres to several kilometers (CHAPMAN and LIEM 1995). They are fed by numerous small rivers and intermittent tributaries and drain into Lake George. Mean annual rainfall in the Kibale Forest (1977-1996) has averaged 1678 mm (range=1205 to 2139 mm). There are distinct bimodal wet and dry seasons. May through August and December through February tend to be drier than other months, with the May-August dry period of a longer duration than the second dry season.

The study site was a small intermittent stream (Inlet Stream East of the Rwembaita Swamp) that feeds the Rwembaita Swamp system, one of the largest papyrus swamps in the Park (approximately 6.5 km in length, Site 7 in CHAPMAN *et al.,* 1999). The stream flows through swamp forest and then secondary forest before entering the swamp. Fish were collected from a 220-m stretch of the stream just before its confluence with the papyrus swamp. This section of the stream averaged 18 cm in depth and 155 cm in width when measured during the early dry season.

Barbus neumayeri reaches a maximum length of 12.5 cm TL in Kibale National Park and feeds principally on small insect larvae, aquatic plants, and detritus (CORBET, 1961; CHAPMAN, unpubl. data.). The species is widely distributed in East Africa (GREENWOOD, 1962, 1966), and is found in a variety of habitats within Kibale National Park including seasonal streams, papyrus swamps, and permanent streams and rivers (OLOWO and CHAPMAN, 1996, CHAPMAN *et al.*, 1999).

Dissolved oxygen concentration, water temperature, and water level were recorded on a monthly basis at the Inlet Stream East. Duplicate samples of dissolved oxygen and water temperature were recorded using a YSI meter (Model 51B) at four stations in the stream between 1100 and 1400 h. Rainfall data were collected at the Makerere University Biological Field Station, which is about 3 km from the Inlet Stream East.

Fish were collected monthly between June 1991 and August 1992 using baited minnow traps set at the four stations where environmental data were recorded. An average of 29 fish per month were collected; all remaining fish were measured (TL) for size frequency analysis and returned to the site of capture. Fish used for gonad analyses were preserved in formalin and later transferred to 70% ethanol. Total length and weight, degutted weight, sex, state of gonadal maturity, and gonad weight were recorded. Maturity stages were modified

from DE SILVA *et al.,* (1985) and HARIKUMAR *et al.,* (1994) on a scale of I=immature to VI=spent. The gonado-somatic index (GSI) was calculated as the ratio of the gonad weight to body weight (excluding gut and gonad) and expressed as a percentage. The size of a mature fish was determined by examining the size of fish with advanced stages of gonadal maturation (stages IV and VI).

RESULTS

Mean monthly water temperatures in the Inlet Stream East varied little over the year averaging 16.9 °C and ranging from 13.1 and 18.4 °C (Figure 1). Oxygen levels were low in the stream, averaging 2.5 mg l^{-1}, but varied over the year from 1.2 to 3.6 mg l^{-1} (Figure 1). There was no relationship between water temperature and monthly rainfall (Pearson correlation, r=0.142, P=0.339). Dissolved oxygen concentration was correlated with rainfall (r=0.64, P=0.033). In general, peaks in dissolved oxygen were associated with seasonal peaks of precipitation (Figure 1). Water level varied markedly over the year with a maximum range of 300 mm and was positively correlated with rainfall (r=0.552, P=0.031, Figure 1).

Each value for water temperature and dissolved oxygen concentration represents the average of duplicate samples of four stations in the stream. Water level change represents one site within the stream, measured on two sequential days each month. Rainfall data were collected at the Makerere University Biological Field Station located approximately 3 km from the stream.

A total of 399 fish were collected from the Inlet Stream East. The sex ratio over the entire sampling period for these specimens was 2.3 males to 1 female. The mean and maximum size (TL) of female *B. neumayeri* (mean=7.5 cm; maximum=10.6) were larger than males (mean=6.9 cm; maximum= 8.9, t=4.98, P<0.001); however, the estimated size at maturity was the same (6.0 cm, TL) for both sexes.

Monthly changes in the mean gonado-somatic index and the percentage of mature fish (stages IV and V) were used to evaluate seasonal patterns of reproduction. Stage V and VI individuals occurred in most months in both sexes indicating that some fish are ripe throughout the year. However, seasonal peaks in gonado-somatic index for fish greater than 6.0 cm (TL) were evident. Comparison of monthly GSI values with the annual pattern of rainfall demonstrates that seasonal peaks of reproduction coincided with seasonal peaks

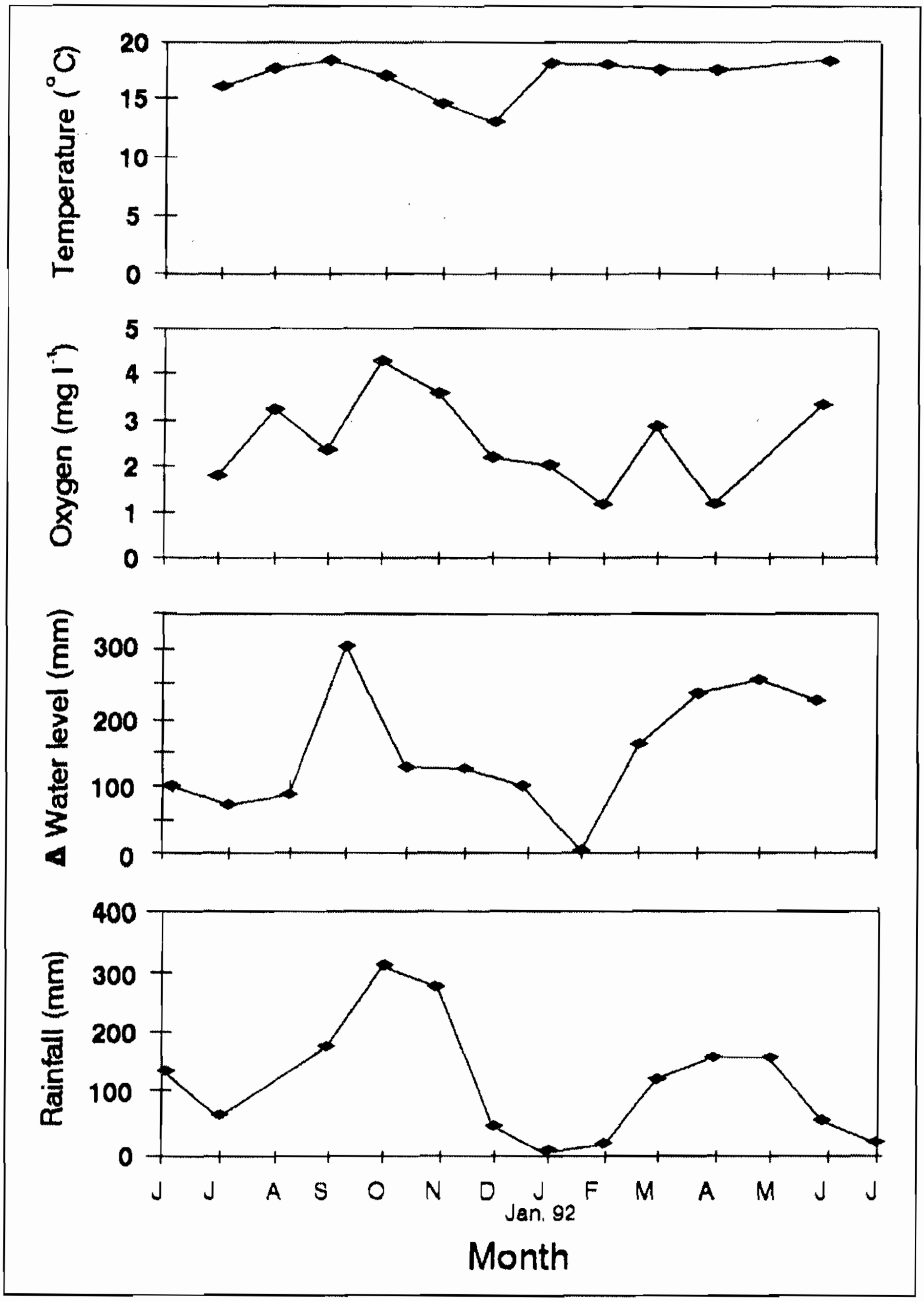

Figure 1: Monthly values a) water temperature (°C), b) dissolved oxygen concentration (mg l^{-1}), c) water level change (mm), and d) rainfall (mm) for the Inlet Stream East of the Rwembaita Swamp in Kibale National Park, Uganda

of precipitation (Figure 2). The mean GSI values increased to high levels just prior to seasonal rainfall peaks. The maximum monthly GSI value was 32.4 and the maximum individual GSI value was 41.9. The rapid drop in the mean GSI values coincided with high rainfall suggests high levels of reproductive activity. The number of fish with gonads in advanced stages of development (IV to V) expressed as a percentage of the fish greater than 6.0 cm was positively correlated with the GSI for both males ($r=0.751$, $P=0.003$) and females ($r=0.772$, $P=0.015$). More fish were in advanced stages of gonadal development prior to seasonal peaks of precipitation. The gonado-somatic index for both males and females was not correlated with monthly rainfall during the month of the GSI sample, but was negatively correlated with monthly rainfall values for time periods 1 mo and 2 mo prior to GSI samples (Table 1). This supports the idea that the lowest GSI values occur 1 to 2 mo after seasonal precipitation peaks.

A total of 2452 *B. neumayeri* were captured at the Inlet Stream East over the period of study. Monthly changes in length frequency distributions suggest two major periods of juvenile recruitment: June-August, and November-February (Figure 3). However, juvenile fish were present in all months suggesting that a modest level of spawning activity occurs during the drier periods. In addition, the largest size categories were absent during the drier periods, July-August of 1991 and December-February of 1992, although there was still an abundance of adult fish.

Rainfall period	Gender	Pearson's r value	P value
Time 0	male	-0.206	0.379
female		-0.121	0.695
1 mo prior	male	-0.740	0.002
female		-0.589	0.034
2 mo prior	male	-0.681	0.007
female		0.649	0.016

Table 1: Results of correlation analyses between the mean gonado-somatic index (GSI) of male and female *Barbus neumayeri* and monthly rainfall values at the time of the GSI sample (Time 0), 1 mo prior to the GSI sample, and 2 mo prior to the GSI sample

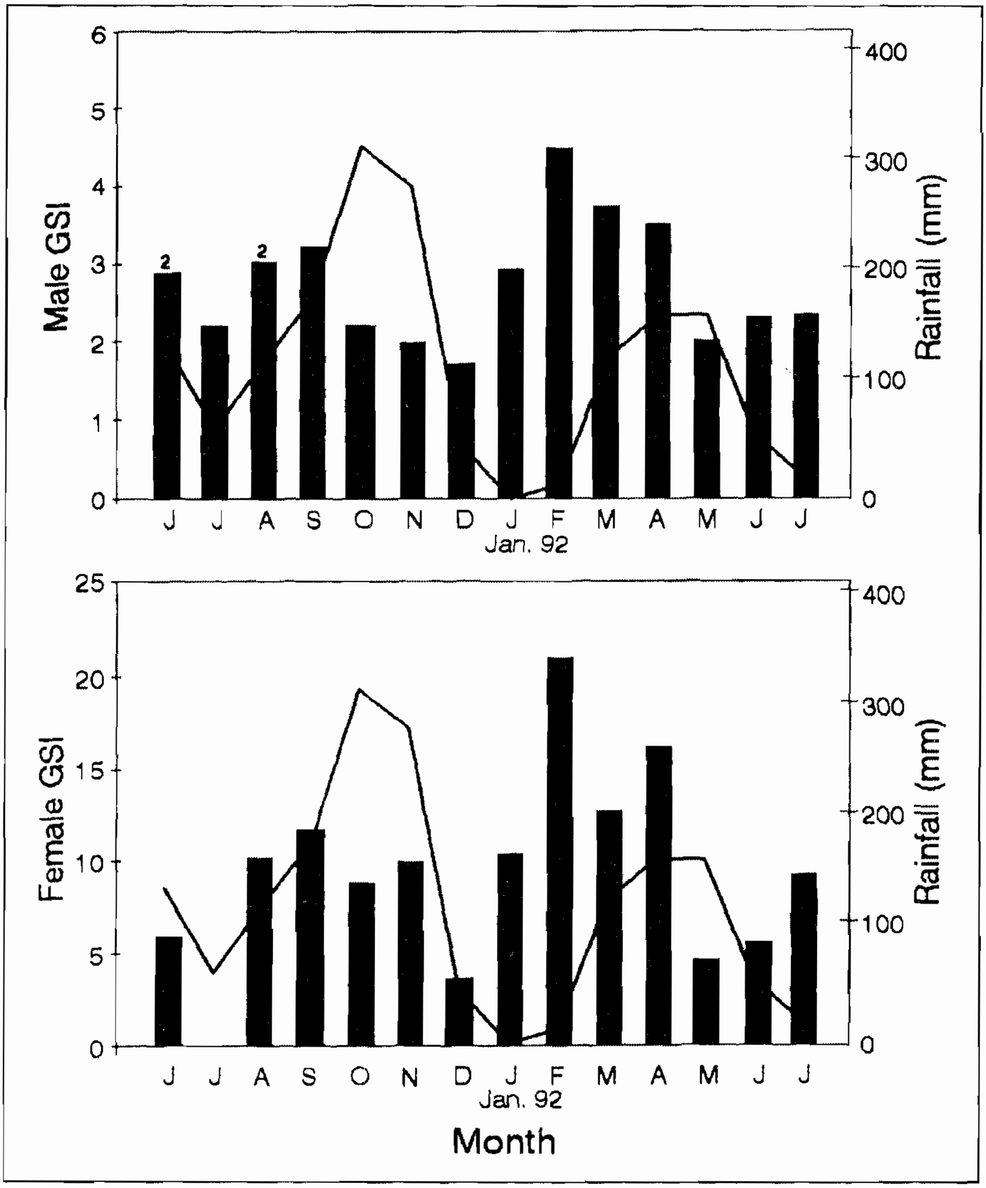

Figure 2: Seasonal changes in the mean gonado-somatic index (GSI) for a) male and b) female *Barbus neumayeri* ($\geq$60 mm, TL) from the Inlet Stream East of the Rwembaita Swamp, relative to the seasonal pattern of rainfall (mm). Months when less than three individuals were collected are indicated as a number on top of the bar.

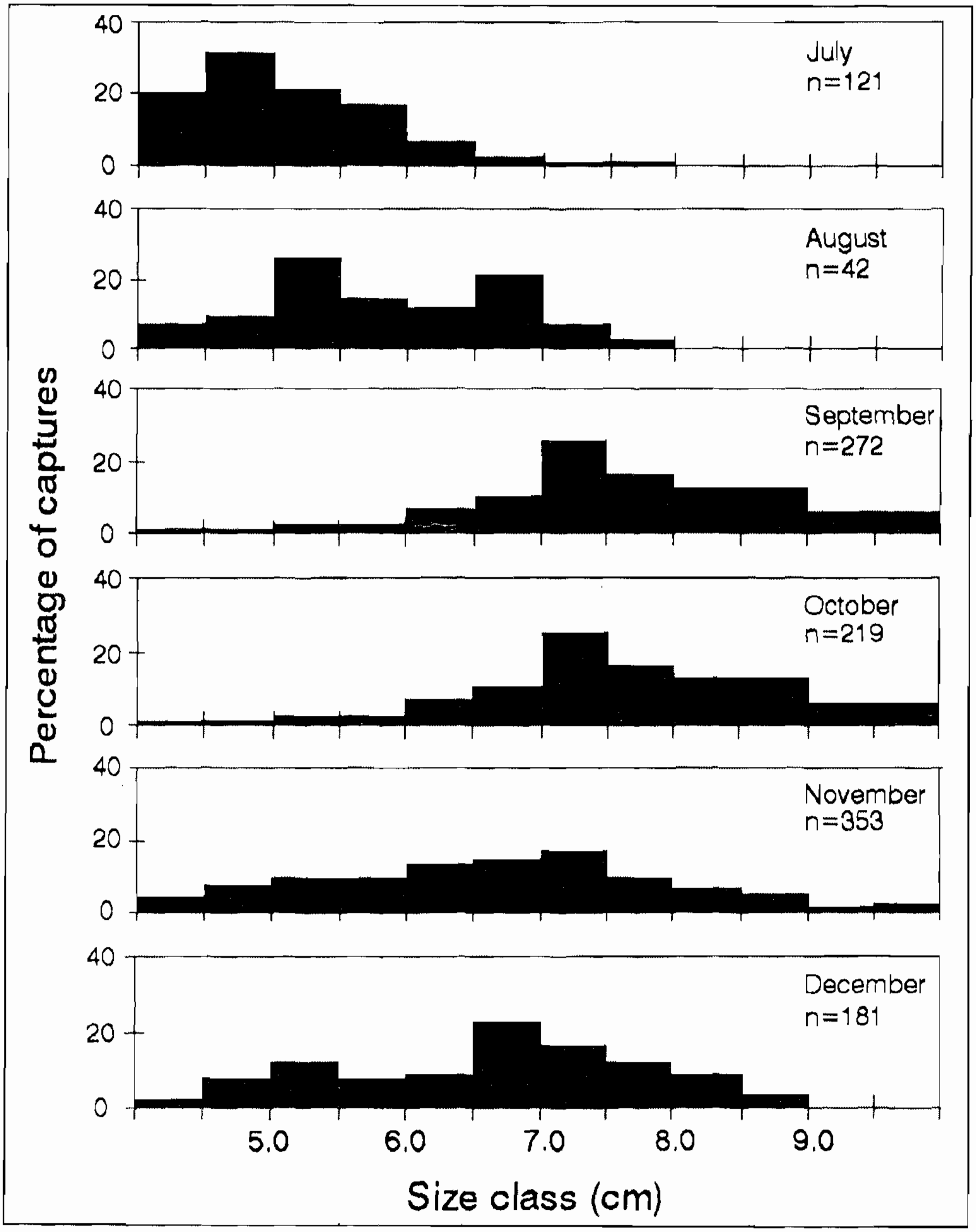

Figure 3. Size distribution of *Barbus neumayeri* in the Inlet Stream East of the Rwembaita Swamp over 12 mo. Size classes are 0.5 cm (TL) except the first size class which represents fish less than 4.5 cm and the last size class which represents fish greater than 9.5 cm. The sample size for each month is indicated in the upper right-hand section of each histogram.

DISCUSSION

The reproductive pattern of *Barbus neumayeri* shows two spawning peaks during the wet seasons. Rainfall or some other environmental character correlated with rainfall may be an important cue. In seasonally flooding waters, dry season conditions lead to habitat contraction, higher fish densities, and in some cases lower fish condition, higher levels of parasitism, and higher mortality (LOWE-MCCONNELL, 1964, 1975; CHAPMAN *et al.*, 1991; CHAPMAN and CHAPMAN, 1993a,b). The absence of very large fish that we observed in the drier periods may represent increased levels of mortality at this time, since there is no evidence for a mass dry season emigration from the stream (CHAPMAN *et al.*, 1999). In the Inlet Stream East, potential benefits of seasonal peaks in reproduction that correspond to high water periods include high oxygen levels, increased availability of habitat, and less competition among juvenile fishes for food and other resources.

Rainy season spawning is well documented among other *Barbus* species in Africa. GAIGHER (1976) found that spawning in *B. kimberleyensis* in the Hardap Dam of South West Africa was coincident with peak seasonal rains. Several seasonally spawning *Barbus* have well-defined seasonal runs up rivers and streams to spawn at the start of or early into the rainy period. PAYNE (1975) found that *B. liberiensis* showed movement upstream and a single discrete breeding season coinciding with the early part of the rains. In a small tributary stream of Lake Victoria near Jinja, Uganda, WELCOMME (1969) reported well-defined seasonal migrations in three *Barbus* species (*B. kerstenii*, *B. apleurogramma*, and *B. paludinosus).* He classified these three species as potamodromous fishes that depend on the river for breeding and early development and on the lake for adult existence. In the Nzoia and Sondu rivers, both tributaries of Lake Victoria in Nyanza Province, Kenya, WHITEHEAD (1959) reported *B. altianalis, B. nummifer (=B. jacksonii),* and *B. doggetti (=B. radiatus)* to be anadromous, with breeding coincident with seasonal flooding. However, WHITEHEAD (1959) classified *B. apleurogramma* as a non-anadromous species and found adults and juveniles in the rivers, streams, swamps, and floodwater pools of Lake Victoria during the dry season. He also found ova in the grasses of a lakeside stream when the stream was not in flood. Adult and juvenile *B. apleurogramma* occur in the heavily vegetated swamps surrounding Lake Nabugabo, Uganda in both the dry and wet season (*pers. obs.*). This suggests that populations of the same species of *Barbus* may differ in their reproductive seasonality and migratory

tendencies. Interestingly, no evidence of well-defined seasonal migrations of *B. neumayeri* was found in the swamp/stream systems of Kibale National Park. *Barbus neumayeri* are found in the intermittent streams and the dense interior of papyrus swamps throughout the year. Fish are more active during the rainy season and exploit a much broader range of the swamp and stream habitat (CHAPMAN and LIEM, 1995), but dispersal between stream and swamp habitat is limited (CHAPMAN *et al.*, 1999). Further studies of *Barbus neumayeri* in other systems such as larger permanent rivers or lake tributaries may, however, reveal more well defined seasonal movements.

Although rainy season spawning is common among *Barbus* species in Africa, other reproductive patterns have been recorded in Africa and elsewhere. LOISELLE and WELCOMME (1971) reported a dry season spawning pattern for *B. sylvaticus* in a forested river in Togo and mentioned a similar pattern in a second forest dwelling species of *Barbus* in the region. A similar pattern also occurs in *B. candens* which inhabits forest streams in the Democratic Republic of Congo (KLEE 1963) and *B. melanampyx*, a hill stream fish endemic to southern India (HARIKUMAR *et al.*, 1994). In the hill stream habitat, conditions are much more constant during the dry season; wet season monsoons create vast changes in water velocity and high turbulence. Dry season spawning may be more common in high gradient streams where floods are likely to be violent and of short duration and therefore remove both fish and food sources and provide little time for populations to exploit inundated areas (LOWE-MCCONNELL, 1979; CHAPMAN *et al.*, 1991). In streams with a lower gradient, such as the Inlet Stream East and the wetlands of Kibale National Park, changes in water flow are less severe, and lateral areas provide a refuge from violent floods and offer longer-lasting, productive waters in which small fish can feed and grow.

The reproductive pattern of *B. neumayeri* shows two distinct spawning peaks. In addition, the distribution of length frequencies suggests two major periods of recruitment. However, the presence of late stage fish and some small juveniles in the population in all months suggests that spawning occurs throughout the year. The tendency to spawn throughout the year may mean that the drier periods in Kibale National Park are not as severe as in many areas of Africa, which have one long dry season per year. In both the intermittent stream and the river, some areas may be suitable for breeding even during the dry season. In a study of six *Barbus* species indigenous to Sri Lanka, DE SILVA *et al.*, (1995) found that three species (*B. nigrofasciatus, B. dorsalis,*

and *B. titteya*) spread their reproductive efforts rather evenly throughout the year. The other three species (*B. bimaculatus, B. cumingi*, and *B. vittatus*) spawned throughout the year but exhibited clear spawning peaks, which coincided with the heavy rains. DE SILVA *et al*., (1985) suggested that the general tendency in these species to spawn throughout the year may relate to the lack of an extreme dry period.

It is likely that the low level continual reproduction in *B. neumayeri* represents a staggered output by different individuals, not perennial reproduction. DE SILVA *et al.*, (1985) showed that maximum monthly and maximum individual GSI values for female *Barbus* spp. that spawned uniformly throughout the year were generally lower (maximum monthly GSI=4 for *B. dorsalis*, 9 for *B. titteya*, and 9 *for B. nigrofasciatus;* maximum individual GSI=16 for *B. dorsalis,* 15.2 for *B. titteya, and* 18.1 for *B. nigrofasciatus)* than the three species that exhibited a wet season spawning peak (maximum monthly GSI=16 for *B. cumingi*, 15 for *B. bimaculatus*, and 9 for *B. vittatus;* maximum individual GSI=37.7 for *B. cumingi*, 38.2 for *B. bimaculatus*, 20.5 for *B. vittatus*). The maximum monthly and maximum individual GSI values of female *B. neumayeri* are much higher than the perennial spawners in the study of DE SILVA *et al.*, (1985) and close to the values for two of the species that exhibit a wet season peak (maximum monthly GSI for *B. neumayeri*=21.4; maximum individual GSI=41.9). HARIKUMAR *et al*., (1994) reviewed the breeding biology of 11 *Barbus* species of S. India and Sri Lanka, including those species reported by DE SILVA *et al*., (1985). They also report higher GSI values in wet season spawners than in dry season or perennial spawners, and more continuous ova size distributions within females of perennial spawners. In *B. neumayeri*, variation in the ova size of individual females appeared to be very low as is more typical of wet season spawning *Barbus.*

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Aspects of the Fishery of Lake Alau in Nigeria

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ABSTRACT

Aspects of the fisheries of Lake Alau located in the North East semi-arid zone of Nigeria were studied to update existing knowledge of the lake's fisheries. The aspects studied included characteristics of the fishing community, catch, fish processing and marketing. Eight fish landing sites were identified along the shoreline. 207 full-time fishermen were recorded operating with 177 boats. The damsite was the most important fish-landing site in the reservoir accounting for 67% of the boats. 883 part time fishermen were also recorded. The fishermen were mostly Nigerians with a few others from neighbouring countries. The gear used mostly in the reservoir is the Malian gura trap. Hooks and gill nets are also considerably used. Sixteen species of fish were identified with Cichlids dominating, constituting 81% of the catch by number and 56% by weight. A production value of 870 mt a^{-1} and a standing crop of 155 kg ha^{-1} were estimated for the reservoir. At $0.70 kg^{-1}, this could fetch an income of over $600,000.00 a^{-1}. To sustain fish production in the reservoir, a regulation of fishermen number and gear size was recommended. Pen cage and enclosure culture methods were also recommended to enhance fishermen's income.

INTRODUCTION

The Alau reservoir (11° 40' N to 11° 45' N; 13° 10' E to 13° 20' E) (Fig. 1) was created in 1987 by damming river Ngadda which takes its source from the Mandara Plateau and is one of the three confluent rivers of the Sambisa floodplains in the semi-arid North East of Nigeria. The reservoir was formed primarily to provide potable water source for the Maiduguri metropolis and to irrigate over 8,000 ha of farmlands in the catcment area of the reservoir (CBDA, 1984). Although no fisheries consideration was given from the onset of its creation, the reservoir contributes immensely to the fisheries of the north-eastern region of the country.

There was therefore neither a pre-impoundment nor an immediate post impoundment fishery survey of the reservoir. As a result there is a dearth of information on the fisheries of the reservoir and its management. The earliest and only information available is that of ODUNZE *et al.*, (1995) which reported

on the catch composition, abundance and distribution of the fishes as surveyed in 1990. The purpose of this study was therefore, to update the status of fisheries information on the reservoir. More specifically this work emphasises information on the fishing communities, method, catch characteristics, processing and marketing. It also suggests some management options for the fisheries for sustainability.

Study area

The reservoir (Fig. 1) is situated in the semi-arid northeast zone of Nigeria. This zone is generally prone to drought (ODNRI, 1989) and characterized by insufficient surface water resources. Compared to Kiri reservoir ($115km^{-2}$) and Dadin-Kowa reservoir in the same zone the reservoir is small (surface area = 5600 ha; total storage capacity = $1.724 * 10^8$ m^3) and is located on the effluent of the Ngadda river from the Sambisa floodplains. The physical characteristics of the reservoir are given in Table 1.

There are two climatological seasons - a rainy season from July to October (with a mean annual rainfall of 600 mm) and a hot dry season from March to July. The dry season is preceded by a four-month (November - February) period of harmattan. The period is characterised by low temperatures and cold dry north-easterly winds. The vegetation of the study area is of the semi-arid zones in Africa (SAGUA, 1991).

MATERIALS AND METHODS

Frame Survey:

A frame survey using the method of complete census (EKWEMALOR, 1977) was carried out in November 1994. This falls within the flood period in the reservoir. During the survey, which lasted for 3 days, the existing fish landing sites along the entire length of the lake were identified and counted. These were classified into fishing villages, fishing camps or other villages. The number of fishermen boats and fishing gears were also counted.

Catch Assessment

This was carried out using the method of stratified random sampling as in (EKWEMALOR, 1977). Three fishing sites were randomly selected out of eight identified. The selected sites were sampled within a 10 days-sampling period. Six fishing boats were randomly selected from each fishing site and

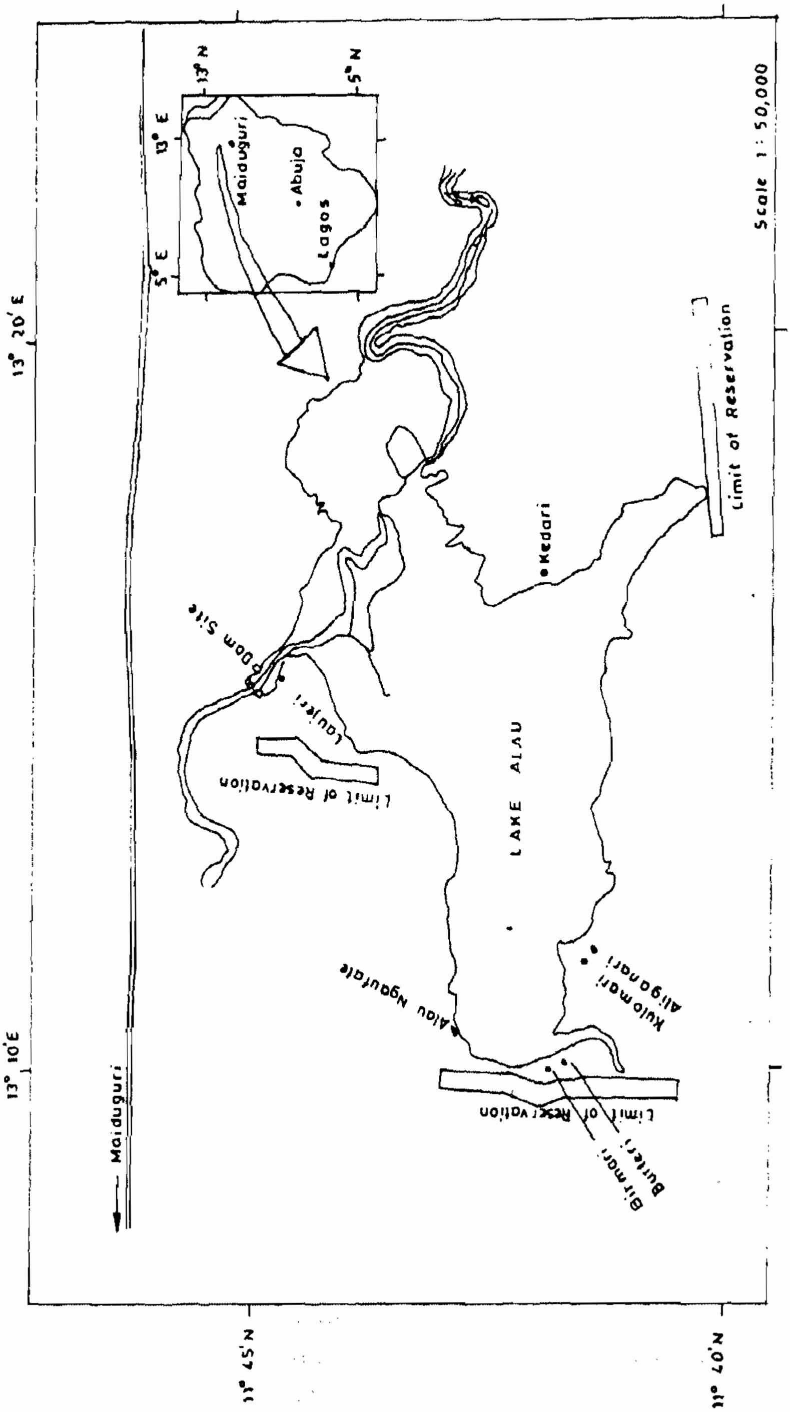

Fig 1: MAP OF LAKE ALAU SHOWING FISHING CAMPS AND VILLAGES AND INSET (NIGERIA)

were sampled for 3 days consecutively. Fish landed by each boat were sorted into species, counted and their weights taken. The weight recorded for each boat and fishing site were then used to estimate the total monthly and annual fish landings for the entire lake. For the purpose of the estimate, the lake as a whole was regarded as a Principal Sampling Unit (PSU) because of its small size and relatively little number of boats.

Table 1: Physical characteristics of Lake Alau (CBDA, 1994)

PARAMETER	VALUE
Average annual run-off	1.62 $*10^8$ m^3 m
Type of dam	Zoned Earthfill Dam
Crest elevation	331.50 m
Crest length	31.0 m
Dead storage level	324 mAMSL
Top width	4.50 m
Maximum base width	54.0 m
Maximum height	9.50 m
Total storage capacity	1.724 * 10^8 m^3
Dead storage capacity	5.60 * 10^6 m^3
Active storage capacity	1.124 * 10^8 m^3 @ 329 mAMSL
Surface area	5600.00 ha
Spillway width	4.60 m x 4
Spillway level	326.20 m
Spillway type	Free Flow (Ogee)
Mean depth	4.25 m

Source: CBDA (1984) Diyam Consultants (1990)

RESULTS AND DISCUSSION

Frame Survey

Fishing Sites

Eight fishing sites were identified along the shores of the reservoir (Fig. 1). Of these, the Damsite, Laujeri and Alau Ngaufate are located towards the northern shore. Kedari, Aliganari and Kulomari are located towards the southern shore. The remaining sites - Birmari and Burteri, are located to the east of the reservoir. Due to the overflowing of the reservoir in September 1994, most of the villages and fishing sites that existed were evacuated and banned from re-establishing in those sites. This accounted for the fewer number of sites identified. Chalmari, a village displaced by the flood on the northern shore had to move to Alau

Ngaufate, a resettlement village. Two of the fish landing sites are fishing camps while the remaining five are villages.

Fishermen

207 full-time fishermen made up of 177 Boat Owners and 30 assistants were counted during the survey (Table 2). These were migrant fishermen comprising of Nigerian nationals such as Kanuris, Marghis, Junkuns and Hausas as well as nationals of neighbouring countries such as Chad, Cameroon and Mali.

Due to the general shallowness of the lake (mean depth 4.25m), a second type of fishermen abound in the reservoir. These are part-time fishermen whose main occupation is arable farming. Their fishing activity is therefore for a short period within the year. They do not own boats, they only set their traps and hooks by wading through the water. They out-number the regular fishermen by far; numbering 883 in all during this survey.

Crafts and gears

177 boats were counted none of which was motorized. 116 of these were found at the Damsite fishing camp (Table 2). Out of the 177 boats only 30 had assistants. This meant single individuals mostly operated the boats. 20 of the assistants came from the Damsite fishing camp.

Four types of fishing gears were identified on the lake. These were the gill nets, Cast nets, Malian gura traps and Hooks. The most commonly used among these was the Malian gura trap followed in order of common usage by the Hook and gill nets. The gura trap (Fig. 2), introduced by the Malians, is extensively used in NorthEast zone of Nigeria. Its intensive use on the Alau lake is convenient because of the shallowness of the lake The trap catches fish indiscriminately and juveniles are as susceptible to it as adult fish. Fish caught in gura traps remain alive until they are retrieved unless preyed upon by carnivores. The bait commonly employed for the trap is boiled husk removed from grains in grain mills. After boiling, the husk is shaped into block forms or any other shape suitable to the user and dried. It is placed in the trap when setting to attract fish into the trap. The trap is particularly efficient in catching *Clarias*.

Hooks were also prominently used on the lake. Gill nets were used in all the stations except in Laujeri. Cast nets were the least common of the gears and were used only to catch live baits for hooks.

Catch assessment

Species composition and distribution

Table 3 shows the list and distribution of fish species recorded in landings along the shores of Lake Alau. Sixteen species belonging to twelve genera and nine families were recorded. *Protopterus annectens* and *Polyterus senegalus* were recorded only at the Damsite. *Gnathonemus senegalensis, Marcusenius isidori, Micralestes acutidens* and *Labeo parvus* were recorded at both damsite and Kedari but not at Alau Nagufate. The remaining 11 species were common to all the three landing sites. A comparison of fish species diversity observed during the current and the previous study in 1990 by ODUNZE *et al.,* (1995) showed that 9 more species and 3 fish families were recorded during this survey (Table 3). This was partly attributed to the variety of gear from which records were made during the current study compared to the previous study during which only catches from experimental gill nets were used. The change observed in species could also be related to the relative's age of the reservoir and the associated stabilisation of the fauna.

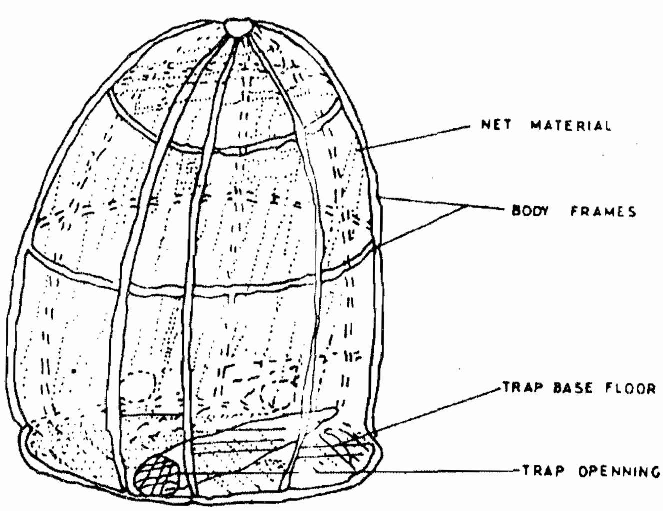

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Fig. 2: THE MALIAN TRAP

Table 2: Distribution of fishermen, boats and gears along the shores of Alau reservoir in November 1994

LANDING SITE	TYPE OF FISHING SITE	NO OF FISHERMEN			TYPE OF GEARS			
		BOATS OWNERS[1]	ASSISTS	PART-TIME	GILL-NET	CAST-NET	GURA TRAP	HOOKS
Laujeri	V	8	-	(150)	-	-	X	X
Dam site	C	116	20	(20)	X	X	X	X
Kedari	C	14	4	12	X	-	X	X
Aliganari	V	10	-	(200)	X	-	X	X
Kulomari	V	5	-	(100)	X	-	X	X
Birmari	V	4	-	(100)	X	-	X	X
Burteri	V	4	-	(120)	X	-	X	X
Alau-Ngaufate	R.V	16	6	(180)	X	-	X	X
		177	30	883				

V = Village C = Fishing campRV = Resettled village

[1] = All boats are non-motorized and operated by the fishermen owners

Table 3: Species occurrence and distribution among the sampled fish landing sites along Alau reservoir in November 1991, and in experimental gill-net catches in 1990 (Odunze, *et al.*, 1995)

SPECIES	FISH	LANDING	SITES	
	Dam Site	Kedari	Alau	Ngaufate (A)
FAMILY LEPIDOSIRENIDAE				
Protopterus annectens	x	-	-	-
FAMILY POLYPTERIDAE				
Polypterus senegalus	x	-	-	-
FAMILY MORMYRIDAE				
Marcusenius isidori	x	-	-	x
FAMILY CHARACIDAE				
Brycinus nurse	x	x	x	x
Micralestes acutidens	x	x	-	-
FAMILY CYPRINIDAE				
Labeo parvus	x	x	-	-
FAMILY SCHILBEIDAE				
Schilbe intermedius	x	x	x	x
FAMILY CLARIIDAE				
Clarias spp.	x	x	x	x
FAMILY MOCHOKIDAE				
Synodontis batensoda	x	x	x	-
Synodontis nigrita	x	x	x	x
Synodontis eupterus	x	x	x	-
FAMILY CICHILDAE				
Tilapia zilli	x	x	x	x
Oreochromis aureus	x	x	x	-
Oreochromis niloticus	x	x	x	x
Sarotherodon galilaeus	x	x	x	x
Hemichromia bimaculatus	x	x	x	-

A further comparison with Tiga, another small reservoir within the same-arid zone shows closeness in the number of species (Table 4). However there is considerable dissimilarity in the species composition of both reservoirs. This could probably be due to the different catchments of both reservoirs, which are widely separated. Alau is within the Chad Basin complex while Tiga's source is from the Jos Plateau; a separation of about 600 km.

Fish Catch

The fish landed by each of six boats for three consecutive days and the three

landing sites is shown in Table 5. Considering the species of commercial importance in the reservoir, the table shows that 81.11% of the fish landed by number were Tilapias. *Clarias spp.* (8.41) and *Schilbe intermedius* followed this. (5.96%). In terms of weight, the trend is the same with Tilapias constituting (56.02%) of the catch. *Clarias spp.* Formed (32.43%) while *Schilbe intermedius* formed 8.87%. These three were the most important species to the fishery of this reservoir. The rest were not commercially important. In the report of ODUNZE *et al.*, 1995, the catches were dominated by Tilapias both by number and weight (48.39% and 54.01% respectively) followed by characids and *Schilbe intermedius*. This differs from the present trend where *Clarias spp.* Ranks second both in terms of number and weight.

Table 4: Comparison of species diversity of Alau and Tiga reservoirs in the semi-arid zone

SPECIES	ALAU	TIGA*
FAMILY LEPIDOSITENIDAE		
Protopterus annectens	x	-
FAMILY POLYPTGERIDAE		
Polypterus senegalus	x	-
FAMILY MORMYRIDAE		
Marcusenius isidori	x	-
Mormyrops deliciosus	-	x
Gnathonenus senegalensis	-	x
FAMILY CHARACIDAE		
Micralestes acutidens	x	-
Alestes nurse	x	x
Alestes denstex	-	x
Alestes baremose	-	x
Hydrocynus forskali	-	x
FAMILY CYPRINIDAE		
Labeo senegalensis	-	x
Labeo parvus	x	-
Barilius senegalensis	-	x
FAMILY BAGRIDAE		
Chrysichthys auratus	-	x
Auchenoglanis occidentials	-	x
Bagrus bayad	-	x
Bagrus docmac	-	x
FAMILY SCHILBEIDAE		
Schilbe mystus	x	x
FAMILY CLARIIDAE		
Clarias lazera	-	x
Clarias sp	x	-
FAMILY MALAPTERURIDAE		
Malapterurus electricus	-	x
FAMILY MOCHOKIDAE		
Synodontis batensoda	x	-
Synodontis nigrita	x	-
Synodontis eupterus	x	-
Synodontis gambiense	-	-
FAMILY CICHLIDAE		
Tilapia zilli	x	x
Tilapia aurea	x	-
Oreochromis niloticus	x	x
Sarotherodon galilaeus	x	x
Hemichromis bimaculatus	x	-

* Source: Ita (1993)

The catch per boat for each of the three landing sites is 23.93 kg for Damsite,

10.07 kg for Alau Ngaufate and 7.17 kg for Kedari (Table 5). 58% of the fish caught (by weight) came from the Damsite. This is not unexpected since the highest concentration of fishermen and boats were found here. The sizes of fish caught in all the three landing sites were small (Table 5). The generally small sizes could be attributed to the indiscriminate fish catch of the most popular gear- the Malian gura trap, the shallowness of the reservoir and the gregariousness associated with the juveniles produced during the breeding activities of most of the species during the floods.

Estimated Landing

The estimated fish landed for the month of November 1994 (coinciding with the flood season) is 72,489 kg or 72.49 mt (Table 6). This gives an annual production of 869.84 metric tons and a standing stock of 155.33 kg ha^{-1}. This figure indicates that the reservoir is highly productive. The production estimate obtained for the Tiga Lake in Kano State ranged between 1526.0 and 1840.8 mt yr^{-1} (BANKOLE, 1988). In comparison with Tiga therefore, (a reservoir which is over 3 times bigger than the Alau) the productivity of the latter is remarkable. The bulk of the fish landed was recorded at the Damsite. It follows therefore, that the Damsite is the most important fish-landing site in the reservoir.

Fish Processing

Few of the fishmongers at the Damsite smoked the fish purchased using Altoona kilns. At Kedari landing site the bulk of the fish landed were smoked and packaged in cartons. The only other means of processing observed around the reservoir was sundrying.

Fish Marketing

The bulk of the fish caught was sold fresh at both the Damsite and Alau Ngaufate landing sites. Fishmongers at the Damsite were almost all women while the opposite was the case at Alau Ngaufate. At Kedari fish processed and packed in cartons were sold through Maiduguri to neighbouring states.

Economic and Management Considerations

With an estimated standing stock of 155.33-kg ha^{-1}, this reservoir has a great potential for fish production if properly managed. At a modest \$0.70 kg^{-1}, the annual fish production of 870 mt could fetch over \$600,000.00 yr^{-1}.

Table 5: Catch by species for selected villages for days each in November, 1994

SPECIES	ALAU DAMSITE		KEDARI		ALAU NGAUFATE			TOTAL			
	No	Wt. (kg)	No	Wt (Kg)	No	Wt (kg)	No	%	Wt (kg)	%	Mean Wt (g)
Clarias spp	1222	81.95	480	105.81	332	52.55	2034	8.41	240.31	32.43	118.15
Tilapia spp	16193	275.47	128	14.60	3305	125.02	19626	81.11	415.09	56.02	21.15
Synodontis spp	747	8.00	2	0.010	8	0.15	757	3.13	8.16	1.10	10.78
Alestes spp	270	7.66	7	0.12	2	0.11	279	1.15	7.89	1.06	28.28
Schilbe sp	1202	55.35	171	7.17	69	3.18	1442	5.96	65.70	8.87	45.56
Mormyrid	51	2.25	4	0.10	4	0.21	59	0.24	2.56	0.35	43.39
Protopterus sp	-	-	1	1.20	-	-	1	0.00	1.20	0.16	1200.00
TOTAL FOR 3 DAYS	19685	430.68	793	129.01	3720	181.2 2	24198	100	740.91	100	30.62
%	-	58.13%		17.41%		24.46 %					
No of boats sampled per day	6	-	6		6						
Total No of boats sampled for 3 days	18		18		18						
Catch per boat (kg)	2393		7.17		10.07						
Mean catch per boat (kg)			13.72								

a = Name of sampled village
b = No of boats sampled per day
c = No of boats of frame survey
d = Sum of daily catch for 3 days
e = Raising factor (Rfi) = No of boats in the village / No of selected boats per day
f = d * e
g = Inverse probability raising factor (1/P)
= Total No of boats in the minor stratum / Total No of boats in the selected village
(The entire lake was taken as the minor stratum)

h = Month raising factor
= Total No of fishing days in the month (Ds) / Total No of Sampling in the month (ds)
i = f * g
j = Sum of I
k = Mean of I
l = Monthly total catch = k * h
m = Catch per annum = 1 * 12
n = Catch per hectare (5600 ha)

Table 6: Estimated fish landing from catch assessment survey conducted along the shore of lake Alau in November, 1994

a	b	c	d	e	f	g	h	i	j	k	l	m	n
Dam site	6	116	425.18	19.33	8218.73	1.53	10	12574.66	21746.00 (kg)	7248.67 (kg)	72486.7 (kg)	869.8 (mt)	155.33 ($kg\ h^{-1}$)
Kedari	6	14	181.37	2.33	422.59	12.64	10	5341.56					
Alau Ngaufate	6	16	129.69	2.67	346.27	11.06	10	3829.77					

However, the population of fishermen/unit area of reservoir and thus the fishing pressure exerted on the stocks of the lake is not conducive for ultimate maximum fish production from the reservoir. The current density of fishermen per km^{-2} on the lake was estimated at 3.70. However, HENDERSON and WELCOMME (1974) recommended about 2.0 fishermen/km^{-2}. This, coupled with the great efficiency of the predominant Malian gura trap, could result in overfishing of the reservoir in the near future. It is therefore, imperative that management programmes be introduced to sustain its fish production.

The reservoir is generally shallow and is very promising for pen, cage and enclosure cultures and this could be introduced in the reservoir. Efforts should also be made to reduce the number of fishermen to the recommended standard.

Fish farming in flood ponds should be developed around the reservoir and encouraged among the fishermen through extension services. This involves the construction of fishponds in the shoreline, which will be filled during the flood. Fingerlings caught by the Malian gura trap will be used to stock the ponds and managed. In the six months that ponds usually retain water in this region, the fish would have grown to table size, harvested and sold.

All legislation for the management of the fisheries, including regulation of fishermen's numbers and gear should be enforced through the Chief Fisherman of the lake. These chiefs are known to command immense authority among the fisherfolk in this region. These measures if implemented could turn this reservoir into an important source of fish and fish products in the North East semi-arid zone of Nigeria especially with the dwindling fortunes of the fishery of Lake Chad.

ACKNOWLEDGEMENT

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Laboratory and field assessment of the eco-toxicological effects of the indigenous molluscicide *Phytolacca dodecandra* (Endod - 44) on the aquatic ecosystem in Cameroon

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ABSTRACT

The effects of the water extract of several varieties of berries of *Phytolacca dodecandra* L'Herit (Endod-44) (Phytolacceae) of different origins on the aquatic ecosystem were investigated. In the laboratory, the Cameroonian Endod-44 was found the most effective variety against adult *Biomphalaria pfeifferi* snail with a 24 hr LC_{50} of 2.16 mg/1 compared to the Zimbabwean and Ethiopian varieties whose 24 hr-LC_{50} was 9. 28 mg/1 and 6.70 mg/1 respectively. At subacute concentrations (1 and 2 mg/1) Endod-44 showed a significant ($p<0.001$) adverse effect on the ability of *Biomphalaria pfeifferi* to lay eggs, conversely, it did not significantly affect the hatching of these eggs even at higher concentrations (4 and 10 mg/1). Under simulated field trials, Endod-44 did not significantly affect the biological diversity of diatoms. The growth of mixed alga was not significantly affected. At 10 mg/1, the Ethiopian Endod-44 provoked a 100% and 70% mortality among adult *Biomphalaria pfeifferi* snails and among fingerling *Oreochromis niloticus* fish respectively. Endod application significantly affected the specific conductivity, the total dissolved solids contents and the temperature of pond water, whereas the p^H and the dissolved oxygen content were not significantly affected.

INTRODUCTION

Schistosomiasis is the second most important tropical disease, ranking immediately behind malaria in terms of its socio-economic and health impact (WHO, 1981). Bilharziasis now affects one in twenty of the world's population, or more that 300 million people in 74 tropical and subtropical developing countries (MCJUNKIN< 1975). In Africa, the disease is endemic in all countries except Lesotho. About 500 to 600 million of additional people are made vulnerable to schistosomiasis by poverty, poor housing, lack of sanitary facilities and lack of education.

In Cameroon, schistosomiasis is also a very important endemic disease. In rural areas, it is rapidly spreading because of a number of factors. Water

conservation and management measures, such as dams and irrigation systems are built either to fight drought or to implement large-scale irrigated agricultural development plans. However, these often create new breeding sites for the intermediate host snails. Infected and uninfected people work together in these areas. They drink, bathe and labour in the same canals and bodies of water, which quickly spreads the disease, especially among highly vulnerable children.

In some villages, prevalence can reach up to 90%. It is estimated that several thousand in Cameroon are currently infected with this disease especially in the northern regions.

One of the most effective methods of controlling schistosomiasis is the use of molluscicides to kill the intermediate snail host, which is considered the weak link in the parasite life cycle. The berries of the plant molluscicide Endod (*Phytolacca dodecandra*) have been found to be effective in killing both the snail vector and the cercariae which are both involved in schistosomiasis transmission (LEMMA, 1970, MONKIEDJE *et al.*, 1990). This plant represents therefore, a low cost and efficient way to eradicate the intermediate host, which could be most effective in village or farm communities. A self-help program using locally produced and processed molluscicides, coupled with chemotherapy, could significantly reduce prevalence and intensity of schistosomiasis at very low individual cost (WEBBE and LAMBERT 1983, MADHINA and SHIFF, 1996).

For such a plant molluscicide to be recommended for general use, its adverse effects on aquatic biota must be quantified and documented. This study aimed at evaluating the effects of Endod-44 on the ecology of the aquatic ecosystem both under laboratory and field conditions.

MATERIALS AND METHODS

Dried Endod berries, type 44, were obtained from three sources: the Institute of Pathobiology of the Addis Ababa University of Ethiopia, the Blair Research Laboratory of Harare, Zimbabwe and the Centre of studies of medicinal plants and Research in Traditional Medicine of Yaounde, Cameroon.

Adult *Biomphalaria pfeifferi* snails were collected from the field (Municipal Lake in Yaounde, Cameroon) and acclimated to laboratory conditions for three

weeks. The fingerling *Oreochromis niloticus* fish (measuring 4.6 $\pm$ 0.99 cm in length and weighing 2.40 $\pm$ 1.33 g) used in field experiments were obtained from government fish ponds of Melen Yaounde, Cameroon.

Artificial, simulated ponds were placed outdoors in order to be subjected to fluctuations of the local climate. A system of four basins made of concrete was used as simulated ponds as described by UPATHAM (1972).

Extraction of Endod Berries

The procedure of the extraction of Endod-44 from Endod berries has been described elsewhere (MONKIEDJE *et al.,* 1990).

Snail Bioassay

The Standard WHO method for snail testing (WHO, 1965) was used to assess the molluscicidal activity of various varieties of Endod-44 ground berries of Cameroon, Ethiopia, and Zimbabwe origin on *Biomphalaria pfeifferi*. In order to avoid the toxic effect of residual chlorine in tap water to snails, a natural spring water (temperature 24.1 $\pm$ 0.2 °C; total hardness 62.0 $\pm$ 0.0 mg. l^{-1} as $CaCO_3$; pH 6.2 + 0.2; total alkalinity 75.0 $\pm$ 0.01 mg. l^{-1} as $CaCO_3$; NH_4 - N and total residual chlorine were below detection limits) and glass beakers were used.

Egg laying test

Adult *Biomphalaria pfeifferi* snail in intense egg laying activity were selected. Subacute concentration of the Cameroon Endod-44 strain (1 and 2 mg/1) were tested. Snails were exposed individually for 48 hours. In order to ensure constancy in the concentration of Endod solution during exposure, the latter was renewed after an incubation period of 24 hours. At the end of the 48 hours exposure, the snails were removed from the Endod solution, washed thoroughly in clean spring water and transferred in a beaker containing clean spring water and fed with romaine lettuce. The number of egg masses laid daily was subsequently recorded for ten days. The experiment was repeated three times.

Egg hatching test

One-day-old egg masses containing ten eggs each and maintained on their support were selected. Three different Cameroon Endod-44 strain concentrations (2, 8 and 10 mg/1) were tested. Four egg masses were exposed per Endod Concentration for 48 hours. The Endod solution was renewed after 24 hours of incubation. Following the 48 hours incubation period, the egg masses were removed from the Endod solution, washed thoroughly in clean spring water and transferred in a clean plastic dish containing clean spring water. The number of snails newly hatched was subsequently monitored.

Simulated field studies

Four rectangular concrete basins were installed in the area of the Melen ponds in Yaounde-Cameroon. The basins were labelled A1, A2, B1, B2 according to their arrangement and were filled with about 250 litters of the nearby natural fish pond water respectively and allowed to acclimate for six weeks. The following organisms were collected from natural ponds and introduced in each basin: 20 fingerling *Oreochromis niloticus* fish, and 4 plastic small wire cages containing each 5 adult *Biomphalaria preifferi* snails. After the acclimation period, aquatic insects and frog larvae were observed in all basins where water had a bluish colour.
Each basin was used as its own control. The effects of the Endod-44 treatment on the ecology of each basin were determined by comparing the values of the ecological variables before and after endod treatment.

Snail and fish bioassay: The bioassays were conducted following a protocol similar to that described by APHA (1985) for laboratory testing. Test organisms were allowed to acclimate in basin conditions for five weeks. The snail and fish mortality were recorded 24 hours following the Endod-44 application to the basins.

Diatom biological diversity monitoring: Ten series of five plain 25- by 75-mm glass microscope slides per basin mounted vertically on slide racks constructed of Styrofoam were used for the sampling of periphyton as described by APHA (1985). The mounted slides were ballasted with a stone and suspended in the basin using a nylon string anchored to a wooden stick placed on top of the basin.

One slide per basin was removed weekly and preserved in a 5% neutralising formalin. The slides were subsequently scraped into test tubes containing 1 ml of formalin solution. The biological diversity index of this sample was determined using the Sequential Comparison procedure described by CAIRNS *et al.*, (1968). The sequential diversity index was determined on diatoms.

Algal growth monitoring: The biomass of autotrophic organisms accumulated on the slides was estimated by measuring chlorophyll *a*. Two slides were removed each week per basin. These slides were immediately scraped into test tubes containing 5 ml of aqueous acetone solution. These samples were subsequently analysed for their chlorophyll content with a Hach DR/2000 spectrophotometer following the Method 1002G described by APHA (1985).

Water chemistry monitoring: The water quality variables monitored throughout the study included pH using a Hach portable pH meter, temperature with a mercuric thermometer, conductivity and total dissolved solids using a Hach portable conductimeter and the dissolved oxygen with a Hach portable oximeter.

Application of Endod-44: Because of its availability, the Ethiopian Endod-44 variety was used instead of the Cameroonian one. In order to determine the appropriate field concentration, the 24-h LC_{50} obtained in the laboratory (24-h LC_{50} lab.) was multiplied by a factor according to the following formula proposed by MONKIEDJE (1990):

Field concentration = 24-h LC_{50} lab. + a x 24-h LC_{50} lab.

Where a = percentage of 24-h LC_{50} lab. Value

Values of the "factor a" including 0%, 25%, 50% and 100% were used. These values of the "factor a" corresponded respectively to "field concentrations" of 6.5 mg. l^{-1}, 8 mg. l^{-1}, 10 mg. l^{-1} and 15 mg. l^{-1} that were tested in basins A1, A2, B1 and B2 respectively.

Data analysis

The LC_{50} and LC_{90} values for Endod-44 in laboratory experiments were estimated using the EPA probit analysis computer program version 1.3 used for calculating lethal concentration (LC) written by C. Stephen of the Duluth U. S. Environmental Protection Agency's Environmental Research Laboratory.

The response difference between the control (before Endod application) and treatment (after Endod application) data groups in each basin for a given variable in field experiments was determined using the paired t- Test on the mean data groups. Paired t-Test was considered significant if $p < 0.05$.

RESULTS

Laboratory Studies

Potency of the various varieties of Endod-44

The acute toxic effects of the Cameroon, Zimbabwe and Ethiopian Endod-44 varieties on *Biomphalaria pfeifferi* snails are shown in Table 1. The Cameroon strain was found the most potent Endod-44 strain to *Biomphalaria pfeifferi* snails.

	Cameroon	Zimbabwe	Ethiopia
LC_{50} (mg. l^{-1})	2.16 (1.98-2.56)	9.27 (7.04-10.21)	6.70 (6.20-7.14)
LC_{90} (mg. l^{-1})	2.84 (2.40-5.32)	12.06 (10.82-10.97	7.77 (7.27-9.25

Table 1: Acute toxicity of various varieties of Endod-44 to *Biomphalaria pfeifferi,* after a 24 hr exposure period. (Each result is based upon 10 animals in triplicate tests; C. I. = Confidence Interval; Figures in parenthesis represent 95% confidence limits).

Effects of Endod-44 on the *Biomphalaria pfeifferi* egg Laying capacity

Figure 1 shows the average cumulated number of egg masses laid by each snail as function of time. The Endod-44 at concentrations tested, inhibited significantly ($p<0.001$ by paired t- Test) the egg laying activity of the exposed snail. It was observed that the higher the Endod concentration, the more important the inhibiting effect on the snail egg laying activity.

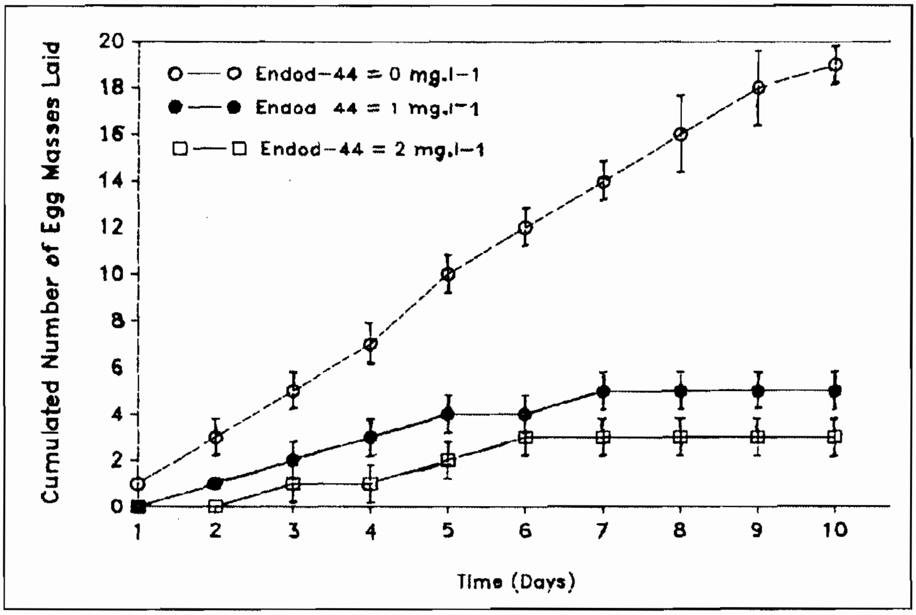

Figure 1: Effects of Endod-44 on the *Biomphalaria pfeifferi* egg laying activity

Effects of Endod-44 on the hatching of snail egg masses

Egg hatching was observed in all egg masses exposed to all the Endod-44 concentrations studied. Dead newly hatched snails were observed. Table 2 shows this effect of Endod-44 on the hatching of the *Biomphalaria pfeifferi* egg masses. Inconsistent mortality rates were observed for the various Endod-44 concentrations tested, thus indicating a negligible effect of this chemical on the hatching activity of snail egg masses. The mortality observed in control and treatment groups could be ascribed to natural causes and/or to residual Endod-44 concentrations on the egg membranes or the egg mass support.

Endod-44 Concentration (mg. l^{-1})	Number of Exposed eggs	Number of live Newly Hatched snails	Percentage Of newly Hatched Snails Dead
0.0	42	40 ± 1	4.80
2.4	40	36 ± 2	10.00
4.0	49	43 ± 2	12.25
10.0	40	37 ± 3	7.50

Table 2: Effect of Endod-44 on the hatching the *Biomphalaria pfeifferi* egg masses (average number in triplicate tests)

Simulated Field Studies

Effects of Endod-44 on snail and fish

The effect of Endod-44 on snails and fish during mollusciciding are shown in Table 3. A consistency in mortality rate in relationship with increased Endod-44 concentration was observed. All the remaining fish were dead in all basins 48 hours later.

Basin	Endod-44 Concentration Applied (mg. l^{-1})	Number of *B. pfeifferi* snail before application	Number of *Oreochromis niloticus* before application	Snail Percent Mortality After Application	Fish percent mortality after application
A1	6.5	20	20	60	15
A2	8.0	20	20	95	20
B1	10.0	20	20	100	70
B2	15.0	20	20	100	75

Table 3: Acute toxicity of Endod-44 to snails and fish in basins (after24 hours

No aquatic insects and frog larvae were observed in the basins following the Endod application. The colour of the water in basins had changed from bluish to greenish six days after the Endod application. The greenish colour of water disappeared seven days later and insect larvae were observed again in the basins. Fourteen days after the Endod application small snails were observed in the basins and 28 days after, snails were abundant.

Endod concentrations applied to basins included 6.5 mg. l^{-1}, 8 mg. l^{-1}, 10 mg. l^{-1} and 15 mg. l^{-1} in basins A1, A", B1 and B2 respectively. A statistical comparison using the paired t - test on the mean variables measured throughout the study evidenced the effect of these Endod-44 concentrations on the ecology of these basins (Table 4).

Endod-44 Concentration (mg. l^{-1})		Chl *a*	Ecological DI	Parameters DO	Te	CD	TDS	pH
6.5	t	-0.86	-0.16	-0.38	2.82	-2.24	-1.84	-9.38
	p	0.45	0.88	0.71	0.03	0.06	0.11	0.0007
8.0	t	-3.32	0.49	0.07	2.75	-5.82	-5.23	-0.75
	p	0.045	0.65	0.94	0.033	0.0011	0.002	0.48
10.0	t	-0.93	1.22	0.89	2.42	-4.60	-3.76	-0.67
	p	0.41	0.31	0.40	0.051	0.0037	0.009	0.53
15.0	t	-0.31	1.80	0.27	2.80	-4.58	-2.78	-0.06
	p	0.77	0.16	0.79	0.031	0.03	0.032	0.95

Table 4: Statistical comparison ("t" Statistic and "p"-level. With alpha= 0.05) of the basins ecological parameters before and after the Endod-44 application (Chl *a*=Chlorophyll *a*: DI= Diversity index: DO= Dissolved Oxygen: Te= Temperature: CD= Conductivity: TDS= Total dissolved solids).

Effects of Endod-44 on diatom biological diversity.

The variations during the study of the sequential biological diversity of diatoms in the basins are shown figure 2. An increase tendency up to 45 days from the onset of the experiment was observed in the diversity index values followed by an important drop from the 52^{nd} to the 66^{th} day of incubation in all basins. The analysis of the samples revealed the proliferation of the genus *Gomphonema* in all basins.

A statistical comparison using the paired t - test on the diversity index values measured before and after the Endod application indicated no significant difference ($p>0.05$) in all the basins (Table 4). Thus, Endod-44 did not significantly affect the diversity of diatoms. This lack of the effect on Endod could be due to the very short life span of Endod active ingredients in ponds (MONKIEDJE *et al.,* 1994).

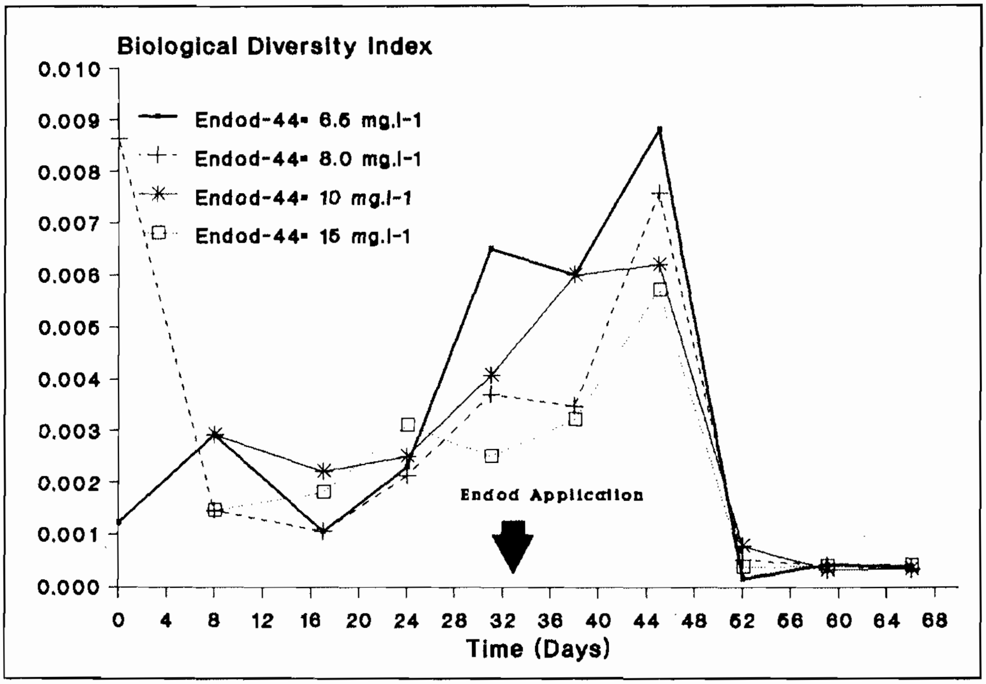

Figure 2: Variations of the diatom biological diversity index in basins

Effects of Endod-44 on basin algal growth

The variations of the chlorophyll *a* content of basins during the study are depicted in Figure 3. A tendency of increase and decrease of the concentration of chlorophyll is observed in all basins. This increase in the chlorophyll *a* concentration was statistically significant ($p<0.05$) only for the basin, which received 8.0 $mg.l^{-1}$ of Endod-44. This observation contrasts that made by MONKIEDJE (1990) who showed that Endod-44 increased significantly algal growth during the first three days following application, and thereafter, a decrease in that growth was observed. The difference in the two observations could be explained by the longer sampling period adopted in the present work.

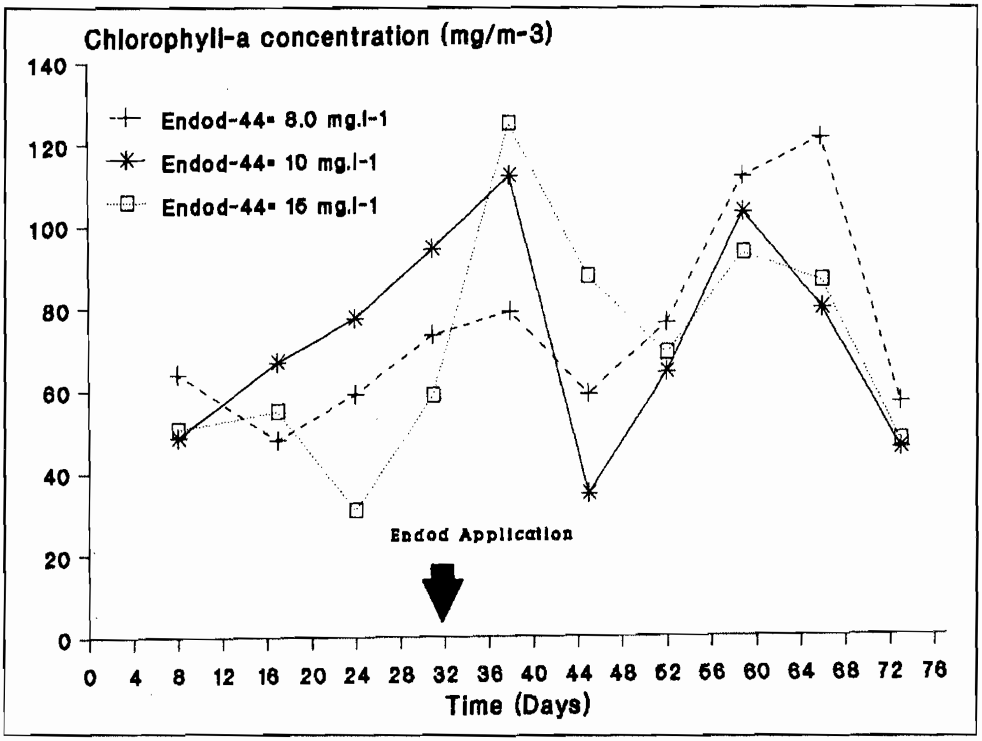

Figure 3: Variations of the chlorophyll-*a* content of basins

Effects of Endod-44 on basin water chemistry

A non-significant ($p>0.05$, by paired t - Test) decrease trend was observed in the dissolved oxygen following Endod-44 application in all basins followed by a rapid recovery. The temperature of the basins varied significantly. A significant decrease in the temperature values following Endod-44 in all basins.

The pH, the conductivity and the total dissolved solids (TDS) of the basins seemed to increase after Endod application. While for pH, this increase was highly significant ($p=0.0007$) only in the basin treated with 6.5 $mg.l^{-1}$ of Endod-44, all basins showed highly significant increase in conductivity. The basin treated with 6.5 $mg.l^{-1}$ of Endod-44 showed a non significant increase in TDS after mollusciciding (Table 4).

DISCUSSION

Under laboratory conditions all the Endod-44 varieties tested indicated a 24-h LC_{50} and a 24-h LC_{90} values for *Biomphalaria pfeifferi* snails lower than most of the literature values.

MONKIEDJE *et al.*, (1994) found a 24-h LC_{50} for Ethiopia Endod-44 strain of 5.37 $mg.l^{-1}$ on adult *Biomphalaria pfeifferi* snails. The literature cities a 24-h LC_{100} of 6.5 $mg.l^{-1}$ Endod water extract for *Biomphalaria pfeifferi* (LUGT, 1981). The 24-h LC_{90} of crude ground Endod berries was 23 $mg.l^{-1}$ for *B.glabrata* (GETANEH and LEMMA, 1977). The Endod-44 toxicities found in the present study seem greater than those cited in the literature. This could be ascribed to the efficiency of the extraction procedure (MONKIEDJE *et al.*, 1990).

The test of Endod-44 on the hatching of the *Biomphalaria pfeifferi* egg masses indicated that there was no significant difference in the mortality rates observed in various Endod-44 concentrations tested. LUGT (1981) reported that there was no significant difference among the *B. glabrata* egg mortality rates when exposed to various Endod-35 concentrations.

This lack of effect of Endod on the egg hatching is ascribed to the inability of the high molecular weight active ingredients of Endod-44 to cross the *Biomphalaria sp.* and *Bulinus* sp. egg envelop (LEMMA and YAU, 1974).

Under field conditions, snails and fish were affected by all the Endod-44 concentrations tested during mollusciciding. A consistency in mortality rate in relationship with increased Endod-44 concentration was observed. Similar relationship had been observed by MONKIEDJE *et al.*, (1994) who reported mortality rates of 50% and 100% among *Biomphalaria pfeifferi* and *Oreochromis niloticus* fish respectively for an increase of 12.5% of the Lab. LC_{50}; for an increase of 50% of that Lab. LC_{50}, 95% and 100% mortality rates in snail and fish respectively. Higher Endod field dose required to achieve 100% mortality among snail population, have been cited in literature. LUGT (1981) reported doses of 34.6 mg. l^{-1} and 97.7 $mg.l^{-1}$ for Bati and Salmenie rivers respectively in Ethiopia. LEMMA (1970) reported doses of 100 $mg.l^{-1}$ for 6 hours, 100 $mg.l^{-1}$ for 3 hours, and 50 $mg.l^{-1}$ to 70 $mg.l^{-1}$ for 6 hours for the Assam river, lake Hora Abijata and an irrigation canal, respectively in

Ethiopia. The variation in these reported field doses could be explained by the specific conditions such as volume, flow and ecology of each body of water to be treated.

The proliferation of snails observed in the basins 28 days later following the Endod application can be ascribed to egg masses, since Endod-44 does not affect these eggs. The disappearance of green colour of water in the basin is due to the complete degradation of Endod-44 in the basins, since under field conditions, Endod-44 persists in ponds for 4 to 5 days, with a half-life of 1.51 days (MONKIEDJE *et al.*, 1995).

When assessing the effect of Endod application on basin water chemistry it was found that the basin dissolved oxygen was not significantly affected whereas temperature was significantly affected. These results contrast those of MONKIEDJE (1990) who reported a significant decrease in dissolved oxygen content of a pond treated with 40 $mg.l^{-1}$ of Endod-44 and non significant decrease in the same parameter in a pond treated with 10 $mg.l^{-1}$ Endod-44; and a significant increase of the temperature. The difference in the two observations could be explained by the longer sampling period adopted in the present work, since Endod-44 persists in the aquatic environment for only 4 to 5 days (MONKIEDJE *et al.*, 1995). The observations made regarding the pH, the conductivity and the total dissolved solids (TDS) of the basins are similar to those of MONKIEDJE (1990) who reported a significant increase in conductivity and TDS following Endod-44 in ponds.

CONCLUSION

In the laboratory, several varieties of Endod-44 of different origins were tested against the snail vector of schistosomiasis, *Biomphalaria pfeifferi*. The Cameroonian Endod-44 was found the most effective strain. At subacute concentrations (1 and 2 $mg.l^{-1}$) Endod-44 showed a significant ($p<0.001$) adverse effect on the ability of *Biomphalaria pfeifferi* to lay eggs, conversely it did not significantly affect the hatching of these eggs even at high concentrations (4 and 10 $mg.l^{-1}$).

Under simulated field trials, Endod-44 did not significantly affect the biological diversity of diatoms and the growth of mixed algae. At 10 $mg.\ l^{-1}$, Endod-44

provoked 100% and 70% mortality among adult *Biomphalaria pfeifferi* snails and fingerling of *Oreochromis niloticus* fish respectively. Endod application significantly affected the specific conductivity, the total dissolved solids contents and the temperature of pond water, whereas pH and the dissolved oxygen content were not significantly affected.

As Endod-44 did not adversely impact the overall ecology of the ponds studied, it is concluded that this plant is well suited for snail control in countries where bilharziasis is endemic such as Cameroon.

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A Review of the effects of population pressure on Watershed Management Practices in the Lake Victoria Basin

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ABSTRACT

Protecting the quality of soil and water while using these resources for the benefit of people is a major challenge in Uganda and indeed globally. Emphasis on agricultural sustainability arises out of increasing awareness about the finite nature of Uganda's arable land resources, the widespread problem of soil degradation, the rapidly deteriorating quality of the environment and the need to preserve soil and water resources for long-term use rather than for short term gain. The current population pressure on forests, swamps, rangelands and marginal agricultural lands leads to inappropriate farming practices, forest removal, and grazing intensities that, in extreme cases leave a barren environment that yields unwanted sediment and damaging stream flow to downstream communities. Watershed management is the process of guiding and organizing land and other resource use on a watershed to provide desired goods and services without affecting adversely the environment. The dilemma in watershed management in Uganda, and indeed globally, is that land use changes needed to promote the survival of society over long-term is at cross-purposes with what is essential to the survival of the population over a short-term. This paper reviews land management practices in the Lake Victoria basin and their impact on the environment. It addresses the current soil status; non-point pollution; timber harvesting/ deforestation; fire effects; grazing by livestock; and wetlands. Emphasis is laid on the effects of these practices on soil and water quality and the overall impact on the lake environment.

Key words: Water quality, farming systems, land degradation

INTRODUCTION

The current population pressures on forests, wetlands, rangelands and marginal agricultural lands leads to inappropriate cultivation practices, forest removal, and grazing intensities that, in extreme cases, leave barren environment that

yields unwanted sediment and damaging stream flow to downstream communities (BOTORE, 1986). Compaction by livestock over the stream source areas increases the net output of water but reduces infiltration rate that aquifers are not recharged, spate flows are increased during the rains and stream flow fails in the dry season (HAMILTON and KING, 1983). Watershed degradation in many countries threatens the livelihood of millions of people and constrains the ability of countries to develop a healthy agricultural and natural resource base (FAO, 1986). HAMILTON and KING (1983) and PEREIRA (1986) concur that watershed management has a critical role in combating land degradation.

A watershed or catchment is a topographically delineated area that is drained by a stream system, i.e. the total land area above some point on the stream or river that drains past that point (*Gregersen et al.*, 1987). Watershed management is the process of guiding and organizing land and other resource use on a watershed to provide desired goods and services without affecting adversely soil and water resources (FAO, 1986). Watershed management practices are those changes in land-use, vegetation cover, and other nonstructural actions that are taken on a watershed to achieve watershed management objectives. The dilemma in watershed management in Uganda, and indeed globally, is that land use changes needed to promote the survival of society over long-term is at cross-purposes with what is essential to the survival of the population over a short term. Emphasis on agricultural sustainability arises out of increasing awareness about the finite nature of Uganda's arable land resources and the need to preserve natural resources for long-term use rather than short- term gain (MAGUNDA, 1993).

This paper reviews a number of watershed management practices in the Lake Victoria basin, in Uganda, and their impact on the environment. Special attention is given to the effect of management practices on water quality. This review addresses soils in the region, non-point pollution, wetlands, timber harvesting/ deforestation, fire effects, grazing by domestic livestock and future research in natural resources management. All these are evaluated from a soil and water management perspective.

A review

Soil and agro-climatic zones

Uganda has a wide range of soils, rainfall and altitudes, which give it considerable diversity and distinct agro-climatic zones. JAMESON and

MACCALLUM (1970) give an excellent account of the climate of Uganda. Uganda has equatorial and tropical savanna types of climate. Most of the country receives between 1015 mm and 1525 mm of rainfall per year. The Lake Victoria region and mountains of Bufumbira, Rwenzori, and Elgon receive higher amounts of over 2000 mm.

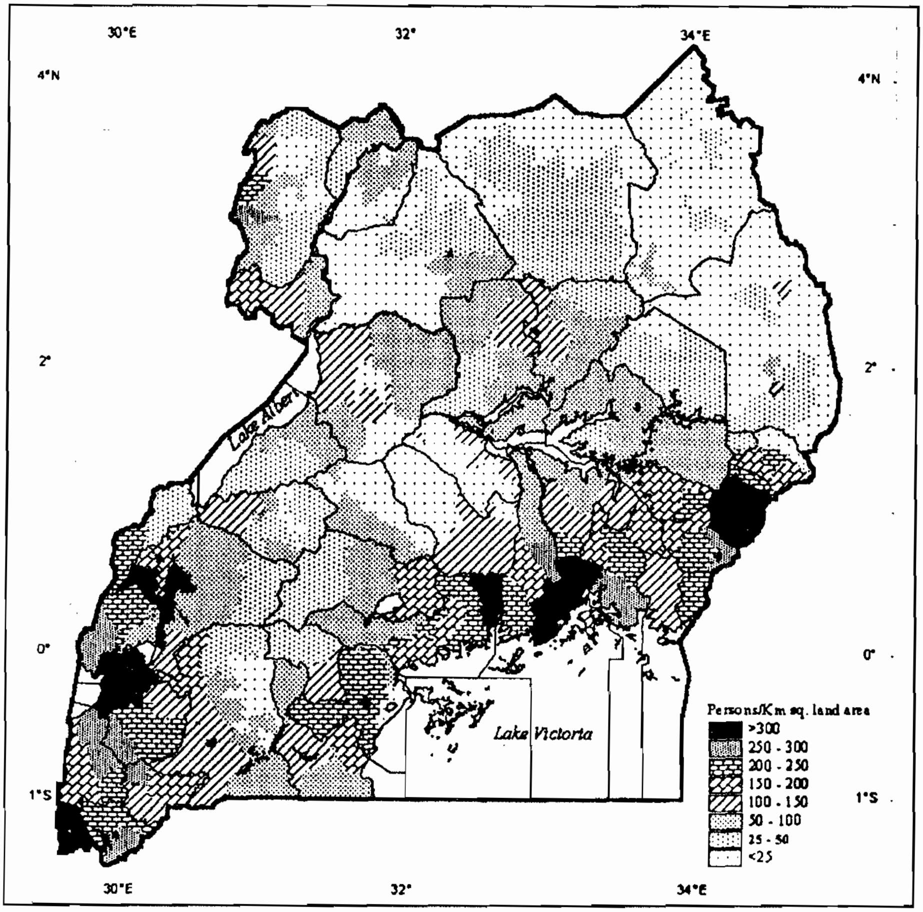

Figure 1. Population density of rural Uganda (Wortmann and Eledu, 1999)

While reviewing the previous 11 agro-climatic zones, Agricultural Research Group 4 (1987) noted that the section of the River Nile from Lake Victoria to Lake Kyoga divides the country into two generalised ecological zones. The north and north-east being characterized by light soils and natural vegetation dominated by short grasses which develop into open savanna forest and south west of the river generally have heavier soils and natural vegetation dominated by the tall elephant grass (*Pennisetum purpureum*), which with tropical forest

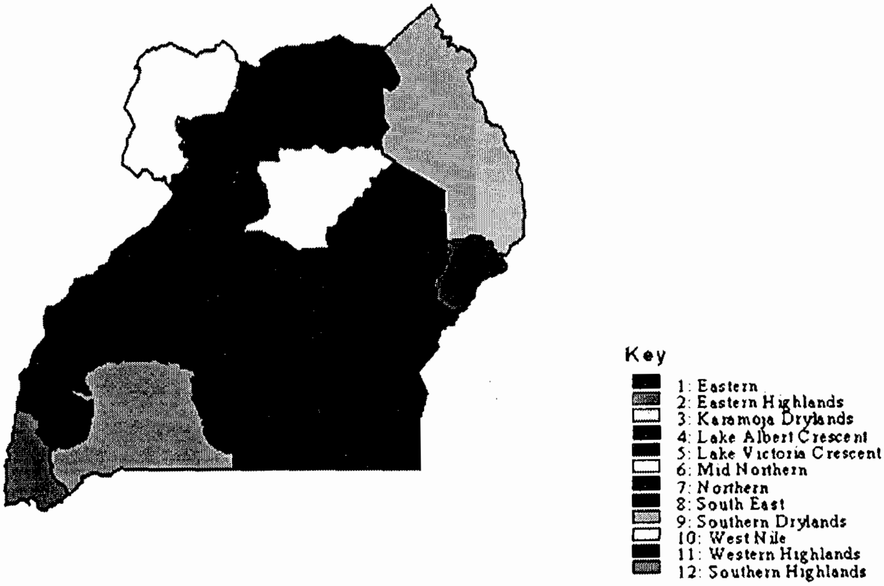

Figure 2. Uganda Agro-Ecological Zones (From NARO Strategy)

trees may develop into climax vegetation of closed tropical forests. These two areas are commonly referred to as the short grass and tall grass areas. By superimposing farming systems considerations and soil patterns on the two broad ecological zones, it was possible to review and rationalise the 11 agro-climatic zones originally defined by the Department of agriculture, into 4 broad agro-climatic zones, for the purpose of research services. Most recently NARO (2000) has further aggregated them and came up with 12 zones. Figure 2 shows the 12 major agro-climatic zones. The tall-grassland zone producing perennial crops in mixed farming systems basically dominates the Lake Victoria basin. The bare hills or pastoral areas in the "cattle corridor" area characterize the western segment of the cacthment.

The true Uganda soil resources are not fully known since only a reconnaissance survey was carried out during 1958-1960. The Lake Victoria basin is dominated by Udic and Aquic soil moisture regimes (SMR) and soil temperature regimes (STR) are isothermic and isohyperthermic. When the rainfall pattern is coupled with the SMR it becomes obvious that runoff / sediment yield from the basin should be high and most of these sediments should end up in the Lake Victoria eventually. Watershed management practices play a vital role in influencing quantities of sediment yield and how much eventually ends up in the lake.

Table 1 shows some typical soil data for different parts in the Lake Victoria basin. It is important to note that although the Lake Victoria basin is designated as 'fertile' the data presented reflects the contrary. A quick scan shows that the pH is generally low (critical level is 5.2 for Uganda soils) in several areas including Mabira forest. Other nutrients are also tending towards low levels. However, it is noted that organic matter is generally high (critical level for organic matter is 3% for Uganda soils) and this could readily find its way into rivers and lakes through soil erosion. The low nutrient status is generally attributed to continuous cultivation without application of fertilizers and inappropriate crop rotations / levy phases.

A quick scan of the data in Table 2 shows the high variability in textural composition. Textural composition helps in characterizing nutrient retention ability and water holding / retention characteristics. Sandy soils (> 45% sand) are generally more prone to the leaching of nutrients and have low water holding capacity. Such soils require very good management practices to be productive. There are extensive belts of sandy soils in the Lake Victoria basin. Those located in wetlands are generally poorly managed.

Impacts

1. Land degradation

The Lake Victoria basin is mainly (80%) an agricultural catchment (WORTMANN and ELEDU, 1999; MAJALIWA *et al.*, 2000). The human population within the catchment is increasing at a rate of about 3% annually. To feed this expanding population more food is required from the already cultivated lands. Unfortunately, however, farming is done at small scale (SFI, 1999), and on land of a quasi-marginal status (RUBAHAIYO, 1991; BEKUNDA and WOOMER, 1996) because of poor management practices (Zake *et al.*, 1992). Non-farming employment opportunities are limited; consequently restorative fallows are too short or inexistent. Forests, and bush are cleared; wetlands encroached to create space for human settlement, road construction, to respond to the new energy demand and, particularly farming activities. Similarly, pastoral areas subjected to a growing human and livestock number, degrade and face severe erosion (MAGUNDA *et al.*, 1999). As a result of soil erosion and nutrient depletion, a generalized state of soil and vegetation degradation and water bodies' pollution is set in the catchment.

Table 1: Soil data for selected parts in the Lake Victoria Basin

Location	pH (H_2O)	OM %	P mg/kg	K cmol/kg	Ca Cmol/kg	Mg cmol/kg	Source
Sango Bay	4.90*	8.06	10.00	0.10*	9.41	4.41	Agambe *et al.*, 1999
Jinja	5.00*	6.33	11.38	0.32*	1.88*	1.00*	Zake *et al.*, 1999
Luwero	6.60	5.22	1.75*	1.09	6.88	3.75	Zake *op.cit*
Entebbe	4.90*	2.00*	94.50	0.51	2.19*	1.20*	Zake *op.cit*
Buwaya	5.40	6.00	8.75	1.28	5.00	2.30	Zake *op.cit*
Mityana	6.20	5.37	29.50	0.13*	8.13	3.00	Zake *op.cit*
Mpoma	5.30*	2.70*	1.75*	0.77	4.38	2.00	Zake *op.cit*
Mabira	5.30*	6.00	-	0.30*	13.10	1.80	Yost and Eswaran (1991)
Rakai	4.5*	8.60	42.8	-	-	-	Majaliwa *et al.*, 2000
Kabanyolo	5.2*	4.31	1.66*	0.54	2.89*	1.67	Nkwiine *et al.*, 1999

Key: OM: Organic matter, P: Phosphorous, K: Potassium, Mg: Magnesium, Ca: Calcium pH: Hydrogen potential

Table 2: Soil texture data for selected parts in the Lake Victoria basin

Location/ District	Clay	Silt	Sand	Source
Mabira forest	51.1	34.8	14.1	KARI
Buikwe	18.0	22.4	55.6	KARI
Mukono/ Ntawo	18.0	36.0	46.0	KARI
Mpigi / Nangabo	12.0	38.0	50.0	KARI
Kabanyolo	45.0	12.0	43.0	Zake *op cit.*
Mpigi / Mpigi	28.0	20.0	52.0	KARI
Mpigi / Maya (Swamp)	32.0	13.0	55.0	KARI
Mityana (swamp)	14.0	7.0	79.0	Zake *op cit.*
Mpigi / Migade	31.0	21.0	48.0	KARI
Kifamba/ Rakai	56.0	6.2	37.8	Majaliwa *et al.* ,2000

KARI: Kawanda Agricultural Research Institute

2. Point and non point sources of pollution

Point source pollution associated with industries or municipalities, whereby pollutants are discharged to natural water systems, is not discussed in this review paper. Watershed management is commonly associated with non-point pollution, which refers to pollution that occurs over a wide area and is usually associated with agricultural activities such as agricultural cultivation, grazing, forest management practices etc. It is important to note that urban runoff represents an important source of non-point pollution, but will not be discussed in this paper. Non-point pollution presents problems to resource managers, both from the standpoint of processes involved and procedures to eliminate, or minimize impacts. VIGNON (1985) points out that a major difficulty is understanding and analyzing the mode of conveyance. Other characteristics that challenge the analyst are the intermittent nature and the extent of non-point pollution. Identifying and quantifying the problem and finding solutions are difficult. As a result, best management practices (BMP), such as contour bunds, agroforestry etc., of watersheds have been identified as an approach to

control non-point pollution. The BMP approach involves the identification and implementation of land-use practices in rural areas that prevent or reduce non-point pollution. Most of these practices are based on soil and water management attributes that promote water infiltration while reducing soil erosion.

Small-scale farmers, who do not, generally, use agricultural chemicals extensively, characterize farming systems in Uganda. Use of chemical fertilizers in Uganda has been declining (ZAKE, 1993). However in the Lake Victoria basin there are several large-scale farming operations that are a cause for concern for non-point pollution viz. Kakira sugar Estate, Lugazi Sugar Estate, various tea estates and the mushrooming number of horticultural farms. All these operations require high utilization of agricultural chemicals but no environmental impact assessment (EIA) has been made on any of these farming systems. The fast growing cut flower industry is located very close to the Lake Victoria fringes basically for two reasons: accessibility of water for irrigation and proximity to Entebbe airport for ease of export of flowers. These farms require constant monitoring of the tail waters that eventually end up in Lake Victoria.

3. Timber harvesting and deforestation

Land-use activities that alter the type or extent of vegetative cover on watersheds frequently will change water yield and, in some cases, maximum and minimum stream flow. When a forest is harvested, a number of important changes occur on a watershed that can change the concentration of dissolved chemical constituents in stream flow. Trees are no longer in place to take up nutrients from the soil and non-commercial parts of the trees left as logging residues increase the amount of decaying forest litter. In addition, the removal of forest canopies makes the site warmer while reducing evapotranspiration (ET). Less ET leads to an increase in soil water content, which, in turn, accelerates the activities of microorganisms, that breakdown organic material, including added slash. Water yield from a watershed usually increases when:

- Forests are clear cut or thinned,
- Vegetation on a watershed is converted from deep rooted species to shallow rooting species, and
- Vegetation cover is changed from plant species with high interception capacities to species with lower interception capacities.

The overall effect of deforestation / change of plant species because of population pressures is increased sediment loading to rivers and lakes in the basin. The sediment loads from such areas are normally high in nutrients and organic matter (FFOLLIOT and BROOKS, 1986). Unfortunately this area has not been investigated in Uganda and effects are only envisaged from the extensive deforestation that has taken place in the area and the concurrently reported increase in organic materials in Lake Victoria.

4. Fire and burning of slash

Most of the farming systems in the Lake Victoria basin are associated with slash and burn land management practices. Burning residues left in the forest timber harvesting produces an even greater increase in the release of ions from the forest litter and mineral soil than the harvesting operation itself. The increased release of ions is due, to a large extent, to the breakdown of organic materials into a soluble form, making them easily removable by leaching. However, in many instances, this increase is short lived (ZOLCINSKI, 1930).

5. Grazing by domestic livestock

Except where overgrazing has occurred in rangelands, grazing by domestic livestock generally does not have a significant impact on the dissolved chemical constituents in stream flow. However when animals become concentrated near water bodies, nutrient loading can be high. More often, the bacteriological quality of water can be affected by grazing of riparian communities.

Degraded rangelands are not extensive in the Lake Victoria basin. However, where they occur they are characterized by compacted soils with high sediment yield that leads to extensive siltation problems (MAGUNDA *et al.*, 1999; MAJALIWA *et al.*, 2000). The barehills in the districts of Rakai, Sembabule, Mbarara and Ntungamo are typical degraded rangelands that require urgent attention/ rehabilitation. Some of these areas are communally grazed and hence there are several socio-economic constraints that need addressing.

6. Wetlands degradation

Wetlands, also known as swamps, are one of the most fragile resources of Uganda and the largest extent is in the central part of the country, around Lake

Kyoga and the banks of Lake Victoria. The hydrologic characteristics of wetlands are:

- Shallow water tables and flat topography,
- The depth of water table governs ET and stream flow discharge from wetlands. The deeper the water table the lower the ET and discharge,
- Annual ET far exceeds annual discharge for most wetlands,
- Wetlands tend to be ground water discharge areas and not recharge areas,
- Because of the flat topography wetlands function as simple reservoirs; they attenuate floods peaks by temporarily storing or detaining water.

Riparian communities are associated with wetlands i.e. plants that grow adjacent to streams or lakes and often have root systems in close proximity to the water. Although riparian vegetation consumes large amounts of water, including ground water, such communities often are valuable for stream bank protection, wildlife habitat and protect adjacent aquatic ecosystems. Under most conditions, the riparian communities along streams and lakes are best left alone or even protected from logging, grazing and other types of exploitation.

Wetlands in Uganda are dominated by histosols, fluvisols and gleysols. Although these soils may be relatively fertile they require special management skills because of the ability, of some of them, to become acidic on drainage (Acid Sulphate soils or Sulfaquents). Lack of research / advisory services, in this area, had led to extensive drainage of swamps that should otherwise not have been drained. There is an urgent need to monitor and evaluate soil properties, soil productivity, hydrologic processes and health impacts of wetlands utilization. Fortunately the need for baseline survey, to determine areal extent and potential of utilization of wetlands, is now well recognized in Uganda.

Table 3 shows analytical data of reclaimed swamps in Uganda. The pH of 2.3 for soils from Kabale (Mr Batuma's farm) is typical of Sulaquents i.e. swampland that should not be drained at all). Several nutrients are also below the critical levels.

Land use and water quality monitoring

There is very little work done, in Uganda, in the area of soil and water quality monitoring in relation to watershed management. The land use management research under Lake Victoria Environmental Management Project is a start in

Table 3. Soil data for selected swamps in Uganda

Location	pH (H_2O)	OM %	P mg/kg	K cmol/kg	Ca cmol/kg	Mg Cmol/kg	Source
Kabale	2.3	42.0	2.63	0.19	0.65	0.10	Zake 1993
Kibimba	5.8	3.70	10.30	1.02	8.75	4.20	Zake 1993
Maya	4.5	1.90	3.00	10.00	33.00	-	KARI
Mityana	3.6	1.10	-	2.00	5.00	-	KARI
Migade	4.2	11.1	4.00	10.00	33.00	-	KARI

Key : KARI (Kawanda Agricultural Research Institute – Kampala/ Uganda)

the right direction to establish relationships between land use and water quality. A good monitoring program should define the problem explicitly (characteristic to measure) and define goals and objectives. Monitoring programs may be aimed at:

- Cause and effect monitoring to determine effects of specific actions on water or soil quality e.g. effect of deforestation on water quality,
- Baseline monitoring to determine trends overtime,
- Compliance monitoring to determine if water quality standards are being met, and
- Monitoring inventory to establish existing water or soil quality conditions and other statistical considerations.

CONCLUSION AND RECOMMENDATIONS

Research in watershed management, and indeed most natural resources, is very limited in Uganda. The majority of sectors in natural resources management research are poorly manned. Natural resources management research benefits are usually long term and consequently did not in the past attract attention of development partners who preferred 'immediate impact programs'. It is however gratifying to note that trends have changed for the better.

Although Uganda has a wide range of soils, rainfall and altitudes, which give it considerable diversity, management of these resources is still poor. The multiple use concept represents a practical means of achieving watershed management benefits while diversifying and increasing the level of income. The scientific community must develop technologies to (a) reduce input while maximizing economic returns, (b) decrease soil degradation, (c) minimize risks of pollution of natural waters and environment, (d) restore productivity of degraded land and (e) maintain productive capacity of existing land by preserving soil's life support processes. The BMP is an approach that has much to offer to make the systems sustainable.

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