Biodiversity characteristics of small high-altitude tropical man-made reservoirs in the Eastern Rift Valley, Kenya

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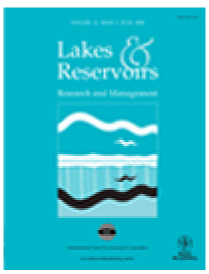

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Abstract

The biodiversity characteristics in eight small (0.065–0.249 km^2) public man-made reservoirs in the central part of the Eastern Rift Valley, Kenya, were studied between 1995 and 1998. A total of 71 phytoplankton species belonging to approximately 50 taxa were identified. Chlorophytes and cyanobacteria dominated the crop. The dominant taxa included *Botryococcus*, *Syunura*, *Microsystis*, *Anabaena*, and *Cosmarium*. A total of over 40 zooplankton species were identified. The community was composed mainly of crustacea, rotifers and protozoa. The most dominant group was *Keratella* but *Brachionus* and *Nauplius* were equally abundant. The diversity and abundance of benthic invertebrates was not high, and only 18 species were identified throughout the study period with the range of species number being 1–7 per reservoir. The benthic fauna was mainly composed of Lumbriculidae and Chironomid worms. A total of six monthly bird counts found an average of 60 birds per reservoir, and a total of 49 species was identified. Ducks, geese and coots dominated the waterfowl, especially during the dry season. Large-scale breeding by Black-headed Heron (*Ardea melanocephala*) and Little Egret (*Egretta garzetta*) was observed

in one of the sites, and other species were also breeding in the reservoirs. The population of waterbirds in reservoirs was closely related to the biomass of benthic invertebrates, and the findings of the study indicate that the structure and dynamics of life forms within small man-made reservoirs can serve as excellent sensors and indicators of the state of watershed health.

INTRODUCTION

Reservoirs are constructed through the establishment of dams, barriers or excavations across rivers, streams or run-off channels. They often reflect the characteristics of both terrestrial and aquatic environments because their construction involves the super-imposition of a riverine ecosystem onto a terrestrial ecosystem. The establishment of reservoirs creates shallow waterlogged areas with unstable substrate and special plant and animal communities that characterize natural wetlands according to the definition by the (RAMSAR) Convention on Wetlands of International Importance (Crafter *et al*. 1992). Man-made wetlands are usually formed around human structures such as reservoirs, irrigation channels, abandoned quarries, sewage treatment ponds, fish ponds and paddy fields.

The number of reservoirs in the world has increased from approximately 5000 in the 1950s to 30 000 in the 1970s and approximately 40 000 in the 1980s (International Council of Scientific Unions – Scientific Committee on Problems of the Environment (ICSU–SCOPE) 1972; Naiman & Decamps 1990; Tundisi 1993). Apart from large reservoirs, most countries, including those in Africa, have numerous small reservoirs created mainly for domestic water supply. The International Commission on Large Dams (ICOLD 1998) recently estimated that there are approximately 800 000 small reservoirs worldwide. (World Wide Fund for Nature (WWF) 1999). The total area occupied by reservoirs is approximately 384 000 km^2.

Many studies have shown that small reservoirs are quite productive ecologically when compared with large reservoirs as a result of the greater area : volume ratio. Small reservoirs are also characterized by frequent thermal instability, which ensures more rapid exchange of nutrients within the water column and at the water–sediment interface (Marshall & Maes 1994).

According to ICOLD (1998), 48% of the world's reservoirs are used for irrigation, 20% are used for hydropower generation and the remainder are mainly used for flood control, domestic / industrial water supply and recreation. In the USA alone, more than 2500 reservoirs are used for recreation and ecotourism. The use of reservoirs by birds, wildlife and fish is known to attract ornithologists, naturalists, hunters and anglers (Patten 1998). Despite the importance of reservoirs, every dam obstructs natural river flow irrespective of size, shape and location, and this impacts upon biodiversity. Goldsmith and Hidyard (1986) and McCully (1996) have extensively documented the environmental impacts of large reservoirs. In Africa, the numerous socioecological changes associated with the construction of reservoirs during the 1960s were largely underestimated (Ibrahime *et al.* 1991).

Classification of reservoirs has been attempted on the basis of various factors including morphometry, hydrology, geomorphology, biota, utilization and ownership. However, a universal classification system is still elusive and existing systems are often very confusing because of regional disparities in climate, hydrology and economic development. Various classification systems have been developed by ICSU–SCOPE (1972), de Silva (1988), Moehl and Davies (1993), Marshall and Maes (1994) and WWF (1999). In this study, an independent system for Kenyan reservoirs was developed based on area, mean depth and seasonal fluctuations in size. In this classification, the surface area and mean depth for large reservoirs exceeds 1 km^2 and 5 m, respectively. Similarly, the area of small reservoirs, as considered here, is in the range of 0.1–1.0 km^2 while the mean depth range is 1–5 m. Pond ecosystems in Kenya have a surface area of <0.01 km^2 and a mean depth of <0.1 m. Both small and large reservoirs are perennial systems that only dry completely during extremely severe drought while the ponds exist only during the wet season.

Despite their widespread distribution, our limnological knowledge of small reservoirs remains small, particularly in Africa. This might partly explain why they are underexploited for recreation, ecotourism, fishery development and biodiversity conservation. The lack of information reflects a historical bias by scientists towards lake and riverine ecosystems. Some African reservoir studies have been conducted about Lake Caborra Bassa (Austin 1968), Lake Kariba (Balon & Coche 1974), Aswan High Dam (Little 1985) and Masinga Dam. The present study aimed to provide information on small reservoirs by considering the biodiversity characteristics of reservoirs in the high altitude central part of the Eastern Rift Valley, Kenya. This paper discusses the seasonal patterns in the composition and distribution of phytoplankton, zooplankton, benthic invertebrates and waterbirds. This paper also compares the biodiversity of the reservoirs with other water-bodies in both the local region in Kenya and other regions in the world.

Characteristics of man-made reservoirs in the Eastern Rift Valley, Kenya

Eight shallow reservoirs located 100–200 km north-west of Nairobi were selected for study. All are situated within the catchments of three Rift Valley lakes, Lake Naivasha (approximately 158 km^2), Lake Elementeita (approximately 20 km^2) and Lake Nakuru (approximately 40 km^2). Lakes Naivasha and Nakuru are presently the only two RAMSAR Sites in Kenya. The rift lakes, situated within the Rift Valley floor at 1700–1800 m altitude, have catchments flanked to the east and west by plateau and escarpments with altitudes that generally exceed 2000 m. Numerous reservoirs are situated within this region overlooking the Aberdare (Nyandarua) Ranges (2000–3000 m elevation) and Mau Hills (2000–2500 m elevation). The distribution of reservoirs in the region is related to elevation, but most reservoirs are high altitude water-bodies. Figure 1 shows the location of the study area while Table 1 shows the general features of those selected for investigation.

Figure 1. . Location of the study area.

Table 1. . The general characteristics of the study reservoirs

Reservoir	**Location**	**Age (years)**	**Area (km^2)**	**Watershed (km^2)**	**Volume (10^3 m^3)**	**Z_{max} (m)**

Table 1. . The general characteristics of the study reservoirs

Reservoir	**Location**	**Age (years)**	**Area (km^2)**	**Watershed (km^2)**	**Volume (10^3 m^3)**	**Z_{max} (m)**
Muruaki	0°38´S,36°33´E	45	0.102	29.1	230	3.5
Kahuru	0°37´S,36°32´E	46	0.088	31.4	240	4.5
Murungaru	0°36´S,36°30´E	48	0.116	57.3	280	3.8
Kanguo	0°12´S,36°25´E	45	0.114	14.1	240	2.2
Gathanje	0°03´S,36°19´E	45	0.119	22.4	400	6.0
Kiongo	0°10´S,36°15´E	48	0.249	0.05	580	3.3
Rutara	0°17´S,36°15´E	46	0.072	1.50	230	3.6
Gathambara	0°27´S,36°02´E	40	0.065	50.0	50	1.5

The reservoirs are fed primarily by surface drainage through river flow, but overland flow and seepage are also common. Surface areas range widely according to seasonal variations in hydroperiod but complete desiccation is rare. The reservoirs have a history spanning 30–60 years having been constructed by colonial farmers who settled in the area during the early to middle twentieth century, mostly from Europe and South Africa. They were mainly constructed to provide a year-round water supply.

Climate in the area is cool and subhumid within the uplands but dry and semiarid within rift floor, with mean annual rainfall of 800–1100 mm (Government of Kenya and Japan International Cooperation Agency 1992). The rainfall pattern is predominantly bimodal with 'long rains' between April and June and 'short rains' in October and November. Like most other parts of Kenya, the period from January to March is the driest. During this time, water levels in most reservoirs can be low and most reservoirs become hydrologically isolated because of the absence of surface-water flow.

The mean human population density in the area is 100–200 individuals/km^2, while the average house density surrounding the reservoirs is 100 units per km^2. This density is almost double at approximately 500 persons per km^2 at Gathanje and Kiongo because of growing market centres adjacent to the reservoirs.

Different communities have evolved within the Rift Valley. Small remnants of tropical subhumid upland forest and woodland are found in the uplands while lowland areas are characterized by *Acacia-Tarchonanthus* bush and scrub. A number of threatened native tree species including *Olea africana*, *Juniperus procera* and *Acacia xanthophloea* are common in the area. Downstream environments within the rift floor provide important habitats for a wide range of herbivores including the buffalo, rhinoceros, hippopotamus, waterbuck, wart-hog and zebra. Lake Nakuru National Park, covering an area of 88 km^2, is an important sanctuary for the lesser and greater flamingos as well as the rhinoceros. In the past, the lake has sustained up to 2 000 000 flamingos at any given time. Lake Naivasha, being a freshwater lake, contains a well-established commercial fishery. The lake sustains over 400 species of birds and 50 species of mammals including approximately 500 hippopotamus. Environmental quality within the rift lakes is deteriorating as a result of land use and land-cover changes in the catchment.

MATERIALS AND METHODS

Fieldwork was undertaken at eight public reservoirs at various months between 1995 and 1998. The main criteria for selection were the nature of the watershed landscape, land cover and land utilization. The reservoirs were in the two major physiographic zones, that is, the highland plateau and rift escarpments. Four reservoirs, Muruaki, Kahuru, Murungaru and Kanguo, are on the plateau, while the rest, Gathanje, Kiongo, Rutara and Gathambara, were in the escarpments. Sampling involved fixed area tri-zonal stratified sampling, which is similar to the single stratified sampling technique used by Balon and Coche (1974) in Lake Kariba. It is based on longitudinal, heterogeneous, biophysical zonation common to most reservoirs (Kimmel & Groeger 1984; Rast & Ryding 1989; Tundisi 1993). This strategy minimizes the clustering effects of simple random sampling (Smartt & Grainger 1974). The reservoirs were initially divided into three strata across the upper (inflow), middle and lower (outflow) zones based on the distance between inlets and dams. A single area-sampling unit (ASU) was randomly selected within each of the three longitudinal strata. The sampling protocol was arranged according to the dominant season in order to assess environmental variations effectively on a seasonal basis. Sampling was carried out in the morning (10.00–12.00 h) and afternoon (15.00–17.00 h) from a dinghy. Most samples were analysed 1 week–1 month after collection.

Biological sampling was aimed to determine species composition and community structure. Composition and density were assessed from 1 mL aliquots sampled from 500 mL vertical water samples, then fixed with buffered 5% formaldehyde. Phytoplankton cells were identified and counted from transects in Sedgewick-Rafter sedimentation chambers using a Leitz inverted microscope. Cell densities were initially expressed as individuals/mL and later converted to cells/L. Collection, handling, identification and counting of phytoplankton followed the procedures of Lund *et al.* (1958), Brower and Zar (1977) and Padisak (1993). Zooplankton were sampled with a 0.14 m diameter, 35 µm mesh net of approximately 0.8 m in length. Hauls were both horizontal and vertical in order to enhance accuracy (Bottrell *et al.* 1976). In vertical hauls, two repeated hauls were combined as suggested by Brandl (1993). In horizontal hauls (transect trawls), the net was trawled 0.5–1.0 m below the surface for approximately 50–100 m between two sites. Surface samples were collected by filtering approximately 10 L of water through the plankton net. After collection, samples were immediately fixed in 4% formaldehyde. Identification and counting was done from 1 mL Sedgewick counting chambers using a Leitz microscope. The assessment was conducted in accordance with guidelines set out by Bottrell *et al.* (1976) and Brower and Zar (1977).

Benthic samples were collected with an Ekman grab sampler (Brower & Zar 1977). Samples were washed through a 1 mm mesh sieve and retained animals were carefully separated from detritus. Large samples were floated in sucrose solution to separate plant and animal matter. Animals were later fixed in 5% buffered formaldehyde. Specimens were identified to the lowest possible taxonomic category and counted using a dissecting microscope.

Waterbirds were counted monthly for 6 months 10–18 h following the area search protocol, as proposed by Rumble and Flake (1982). Birds were recorded by sight and call at different times. Bird observations were generally made from a slowly moving dinghy. Only positively identified birds were recorded; flying birds were not recorded unless they landed near the reservoir, or took flight from the reservoir. Species identification used as instructed by Williams and Arlott (1980) and other aids from the East African Natural History Society (EANHS), and nomenclature followed that of EANHS (1996).

RESULTS

Phytoplankton

Approximately 71 species from approximately 50 taxa were identified. Chlorophytes and cyanobacteria dominated the biomass. *Phacus* was one of the most common genera, with up to six species per site in certain cases. Other common genera included *Euglena, Ceratium, Pediastrum*, *Syanura*, *Anabaena*, *Cosmarium* and *Gonatozygon.* The range of species number was 8–41 per reservoir, with the most dominant taxa composed of *Microcystis aeruginosa*, *Botryococcus braunii*, *Ceratium hirundinella*, *Phormidium autuminala*, *Crucigenia tetrapodis* and *Phacus longicanda.* Both chrysophytes and cryptophytes were always poorly represented, and only increased slightly during February and March. Similarly, euglenophytes were only present during the wet season in June and September. Diatoms were very rare. Figure 2 shows the characteristics of reservoir phytoplankton communities where the highest phytomass occurred during the dry season, with only a minor peak during the wet season. The dry-season peak was determined by light and temperature, while the wet-season peak was determined by nutrients. Most of the phytoplankton crop was in the top 2 m of the water column.

Figure 2. . Characteristics of reservoir phytoplankton communities. (a) Monthly counts by depth, (b) monthly species number by depth, and (c) summary of plankton distribution by depth.

Figure 2 shows that phytoplankton diversity was higher towards the end of the year, during which time the overall phytomass was, however, quite low. Most of reservoirs were dominated by cyanobacteria towards the end of the dry season in February with chlorophytes being subdominant. The cyanobacterial crop was much smaller in the escarpment reservoirs while blooms were widespread in the plateau reservoirs. At the onset of the long rains in March, there was a switch from the blue–green algae to green algae, but the composition was quite uniform in June and September, which are predominantly cold and dry months, respectively.

Zooplankton

Forty zooplankton species were identified, the highest number of species occurring in Kahuru (n = 33) and the lowest number of species in Gathambara (n = 19). Other reservoirs with high diversity of species included Gathanje (n = 28), and Murungaru (n = 25). Generally, reservoirs in the plateau had higher diversity compared to those in the escarpment landscape. The highest zoomasses, as reflected by count data, were in Gathanje and Kahuru, while the lowest were in Kanguo and Rutara. The most dominant taxon was *Keratella* but *Brachionus* and *Nauplius* were equally common.

Figure 3 shows the spatio-temporal characteristics of zooplankton counts. The figure indicates that the lowest biomass was observed in February during the hot and dry season, and the highest biomass was observed in June and July, which are predominantly cold and wet months. The low zoomass in the dry season might be attributed to the widespread presence of cyanobacteria, which are known to be unattractive to zooplankton grazers.

Figure 3. . Spatio-temporal characteristics of the reservoir zooplankton community.

Crustacean biomass was quite high in Murungaru and most of the other escarpment reservoirs except Gathanje. During the dry season, they accounted for 60–100% of the total zooplankton biomass. However, there was a general scarcity of large crustaceans such as *Daphnia*, except at Gathanje, which supports a fairly well-established fishery of tilapia, common carp and crayfish. In the wet season, over 50% of the zoomass in the reservoirs consisted of rotifers.

Macrobenthic invertebrates

The diversity and biomass of macrobenthic invertebrates were quite low with only 18 species identified throughout the study period at a range of 1–7 species per site. The range of abundance was 13–171 individuals per reservoir. The benthic fauna was mainly composed of Lumbriculidae and Chironomid worms. An increase in abundance was noted after the wet season, and could probably be attributed to the accumulation of allochthonous detritus. Louisiana crayfish (*Procambarus clarkii*) accounted for a large proportion of the biomass at Gathanje, although its origin was not clear. However, *Procambarus clarkii* has existed in Kenya for the last 40 years, and occurs in all major drainage systems of the country.

Figure 4 shows the characteristics of benthic fauna in the reservoirs. It indicates little change in species composition during the wet and dry seasons. However, peak diversity was noted at the onset of the long rains in February and later during the wet season (July and September). Slightly higher biomass was noted in the plateau landscape, and is probably attributable to the presence of submersed and floating macrophytes that can offer suitable habitats and promote the accumulation of autochthonous detritus.

Figure 4. . Spatio-temporal characteristics of the reservoir benthic invertebrate community. (a) Species, and (b) abundance.

Waterbirds

Figure 5 shows the monthly count and species number of waterbirds. A total of six monthly counts found 49 species and an average of 60 individuals per reservoir. There was an average species number of 5–25 per site. The number of birds was high during the dry season (December–March) but the diversity was higher in the wet season. The most dominant birds included the Red-knobbed Coot (*Fulica cristata*), Black-headed Heron (*Ardea melanocephala*), Egyptian Goose (*Alopochen aegyptius*), Yellow-billed Duck (*Anas undulata*), Little Grebe (*Tachybaptus ruficollis*), Hadada Ibis (*Bostrychia hagedash*), Blacksmith Plover (*Vanellus armatus*) and Cattle Egret (*Bubulcus ibis*). From the counts, it is evident that the resident avifauna comprises ducks, geese, coots, grebes and egrets. Some of the rare birds included the African Jacana (*Actophilornis africanus*), Macoa Duck (*Oxyura maccoa*), Common Teal (*Anas crecca*) and Hottentot Teal (*Anas hottentota*).

Figure 5. . Monthly distribution of waterbirds in the Rift Valley reservoirs. (a) Count, and (b) species.

The number of stilts, sandpipers, snipes and sunbirds remained quite small throughout the year while the number of predator birds increased during the wet season, which was probably a result of the increase in benthic biomass. There was a predominantly high species number at Kanguo, which is located only 3 km from Lake Ol Bolossat, a small freshwater lake. This might increase the movement of birds between the two water-bodies. The number of the Crowned Crane (*Balearica regulorum*) was particularly high at Gathanje, Murungaru and Kanguo, which are all proximal to Lake Ol Bolossat, a lake that supports a huge population of cranes.

Waterbird breeding was observed in a number of sites within the area. Between November and January, large-scale breeding by Black-headed Heron and Little Egret was observed on *Acacia xanthophloea* and *Ficus* trees at Gathambara. Small scale breeding by Egyptian Geese was observed beneath *Rhus natalensis* shrubs in the isolated islands of Gathanje. In December 1998, up to 20 broods of the Yellow-billed Duck were seen in the western shores of Kanguo reservoir, which indicates that the bird is probably breeding there. Breeding by the Crowned Crane was established in the *Pennisetum-Eleusine* tussocks, which are common in the plateau landscape, especially in the Kinangop area. These sites are seriously threatened by extensive habitat modification occasioned by expanding cultivation and the rapid subdivision of land into small parcels. Other birds that appear to breed in the reservoirs and their environs include the Red-knobbed Coot and the Little Grebe.

DISCUSSION

Reservoir phytoplankton diversity was lower when compared to some tropical lacustrine ecosystems. In Lake Naivasha, Kalff & Watson (1986) have reported over 140 taxa and 1500 species. The diversity of phytoplankton in the small reservoirs was slightly greater than the large Turkwell Gorge Reservoir, Kenya, where over 60 species have been identified (Kiplagat Kotut, pers. comm., April 1999). The Turkwell Reservoir is a relatively recent water-body. Both the age and the size of the water-body play an important role in the structure of the reservoir phytoplankton community because of their influence on physico-chemical limnology.

The dominance of cyanobacteria in the small reservoirs, especially at the onset of the ‘long rains’, is a clear indication of eutrophication progression. Increasing algal biomass that is symptomatic of eutrophic conditions has also been reported downstream within some Rift Valley lakes, such as Lake Naivasha (Harper *et al.* 1993). Cyanobacterial dominance can also be attributed to the low grazing preference by zooplankton. Cyanobacteria also have competitive advantage over other phytoplankton taxa, especially during the dry season, because of their ability to fix nitrogen. This ability enhances survival under conditions of high temperature and nutrient scarcity. The ability of cyanobacteria to commute from the upper water column to the bottom gives them an advantage over other phytoplankton life-forms during the times when phosphorus is locked in the bottom sediments. Cyanobacterial dominance in reservoirs has also been reported elsewhere in Masinga Reservoir on the Tana River (Pacini 1994). In younger reservoirs, such as the Turkwell Gorge reservoir in northern Kenya, chlorophytes are more prominent (Kiplagat Kotut, pers. comm., April 1998).

Figure 6 compares the distribution of phytoplankton and zooplankton in the reservoirs. The number of phytoplankton species was higher than that of zooplankton for all reservoirs except Gathanje and Gathambara. Zooplankton diversity at Gathambara exceeded phytoplankton diversity by a factor of approximately 10 times, but the phytoplankton crop exceeded that of the zooplankton in terms of biomass. This kind of trophic arrangement corresponds well with models, which explains Charles Elton's classical pyramids of numbers (Odum 1971). The distribution of plankton within trophic levels in Gathanje is a case representative of the inverted pyramid of numbers. The scenario at Gathanje indicates that the consumer biomass might exceed that of the producer because the phytoplankton are probably consumed by grazers as fast as they are produced. We attribute this condition to the highly transparent nature of the reservoir (Z_{max} = 6.0 m, Secchi depth = 1.4 m) that enhances grazing by both zooplankton and fish.

Figure 6. . Characteristics of reservoir plankton diversity and counts. (a) Species, and (b) counts.

Figure 7 shows the results of correlation analysis between phytoplankton and zooplankton communities; however, it is difficult to draw firm conclusions on the interactions and dynamics of plankton communities using our data, as it was based on monthly samples as this kind of data fails to effectively capture the fine and occasionally dramatic changes that take place in time and space. According to Bottrell *et al.* (1976) and Cobelas and Arauzo (1994), the most ideal sampling intervals for plankton communities should be less than their generation time, which can be very short, and calls for intensive sampling protocols. The use of daily, or at least weekly, samples appears to be a reasonable compromises but this was not possible during this study.

Figure 7. . Relationships between phytoplankton counts (cells/mL) and zooplankton count (organisms/mL).

The relatively low diversity of benthic invertebrates within the reservoirs corresponds with the findings of other studies undertaken within the area. Barnard and Biggs (1987), for example, found 64 species in the streams of the Lake Naivasha catchment. This was considered to be less than the number found in other tropical streams. Mathooko and Mavuti (1992) have found a similar pattern in the Naro Moru River. Slightly higher diversity has been reported within the lacustrine areas. A total of 80 taxa from the littoral region of the Naivasha, Oloidien and Sonachi lakes was recorded. The low diversity and abundance of benthic invertebrates in the Rift Valley reservoirs is probably caused by their small sizes and relatively young age. This can reduce niche availability because of the low degree of habitat heterogeneity.

The dominance of the benthic community by collector/ gatherer Lumbriculid–Oligochaete worms and predator chironomid worms in the reservoirs is quite similar to the pattern reported for reservoirs in the USA by Parsons and Wharton (1978), Gladden and Smock (1990) and Leslie *et al.* (1997). According to Anderson and Cummins (1979), both oligochaete and chironomid benthos can be quite common in headwater streams but this could not be established in this study because almost all of the sites were in the headwaters. However, benthic communities were more established in the plateau as a result of the presence of fine-textured sediments. Reservoir bottom sediments in the escarpments, had greater content of organic debris of dead biomass from the forested riverbanks.

Fresh deposits of wood debris dominated the composition of bottom sediments at Gathanje, which could have been responsible for the low benthic diversity of three species. Fish grazing might also cause low diversity. The presence of unidentified snails at Gathanje indicates a potential health hazard because the waterbody is heavily utilized by the local people as a source of drinking water. However, there is a possibility that the presence of *Procambarus clarkii* might eventually control the snails. According to Mkoji *et al.* (1999), the potential of *Procambarus clarkii* as a biocontrol agent for medically important pulmonate snails is high because it readily consumes the snails that host trematode parasites of medical or veterinary significance in sub-Saharan Africa.

The high abundance of Chironomid worms at Murungaru, and Rutara indicates the existence of a good fishery potential. According to King and Brazner (1999), Chironomid worms constitute one of the most important sources of food for insectivorous fish. In Lake Naivasha, which supports a fairly well-established commercial fishery, seven Chironomid species have been identified (Litterick *et al.* 1979).

The results of regression analysis between benthos and waterbird counts was significant (r^2 = 0.74, *F-statistic* = 49.9, $P < 0.05$), which showed that the reservoir waterbirds were related to the benthic invertebrate community. Benthic invertebrates provide a primary food source for many waterbirds. Ducks in particular are known to depend heavily on benthic invertebrates (De Szalay & Resh 1997). A wide range of human factors, such as population density, house density and farm size, also demonstrated a strong influence upon waterbird communities.

Field observations indicated that human factors had a negative effect on waterbird communities in some of the reservoirs. The populations of Egyptian Geese and Yellow-billed Ducks in the plateau reservoirs were endangered in some areas, such as Kinangop, by increased hunting and egg gathering, which is conducted on a regular basis both by the local people and visitors from nearby urban areas. Habitat destruction, excessive hunting and egg gathering have been associated with declines in waterfowl populations in wetlands (Naugle *et al.* 1997; Tilmoney *et al.* 1997).

CONCLUSION

The plankton community in the reservoirs was not significantly different from that of other freshwater bodies. Chlorophytes and cyanobacteria dominated the phytoplankton while the zooplankton consisted mainly of crustaceans and rotifers. The results showed that cyanobacterial blooming, which is symptomatic of eutrophic conditions, is not restricted to lakes and floodplain wetlands. Our results show that eutrophication is emerging even within small waterbodies in tropical catchments. This is often a common problem when ecohydrological upsets occur in watersheds as a result of improper land-use practice. Small reservoirs can therefore form excellent indicators and early warning systems for predicting watershed ecosystem disturbance. The increasing eutrophication of small man-made reservoirs in the tropics will greatly escalate the medical problems of water-borne diseases because a huge proportion of rural household water supply is provided by untreated water from public reservoirs. Some of the common ailments attributed to the biotoxins of eutrophication, such cyanotoxins, manifest clinical symptoms that are amazingly similar to those of other water-borne diseases including typhoid and malaria. This can definitely complicate the efforts of water-borne disease control.

The benthic invertebrate community in the reservoirs was not very diverse when compared to other tropical areas. This is most likely a result of their small sizes and young ages. However, the invertebrates have a strong impact on the structure of reservoir waterbirds. The resident waterbird community consists mainly of waders including coots, ducks and geese. Some of the reservoirs provide important breeding areas for waterbirds, and should probably be earmarked for limited protection, preferably through management by the local community. Some reservoirs, such as Gathanje, can form salient local Heritage Sites where ecotourism and fishery development can be introduced and organized, preferably through community-based projects.

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