Macroinvertebrate communities in two tropical reservoirs (Lamingo and Liberty reservoirs) located in Jos, Plateau State, Nigeria

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Abstract: Macroinvertebrates are animals without backbones. Those that are adapted to aquatic life have representatives among a variety of animal groups that include hydras, worms, molluscs and arthropods. Some of them are large enough to be seen with the naked eye though, in some cases, their detailed characteristics can only be appreciated with the aid of a dissecting microscope or an appropriate magnifying lens. This study investigated the taxon richness of macroinvertebrates in two tropical neighbouring reservoirs located in the biotite granite-rock-strewn Lamingo village in Jos North Local Government Area of Plateau state, Nigeria. These two reservoirs are subjected to different levels of human interferences. The overall idea was to provide a preliminary inventory (base-line data) of macroinvertebrate taxa in the two water bodies that will serve as reference sources of information for future works in the reservoirs. A pond net was used to sample the benthic zone at the shallower parts of the reservoirs' littoral zone, in a shovel- and rake-like manner. Benthic matter (mud, silt, sand, small gravels and detritus as well as associated invertebrates) collected was washed through a vegetable sieve and then through a tea sieve - procedures which made it possible to pick out and sort the macroinvertebrates. Captured animals were identified to family level. Lamingo reservoir had more taxa than Liberty reservoir. Out of the 199 animals recorded for the two reservoirs, 80.40 % were recorded in samples collected from Lamingo reservoir. A striking observation was that whereas mollucs (gastropods and bivalves) were present in samples collected from Lamingo reservoir, there was no mollusc recorded in samples collected from Liberty reservoir. The fewer taxa recorded for Liberty reservoir could be as a result of ecological disturbance occasioned by human activities (farming on the catchment area, water extraction, and water tankers driving into the reservoir to collect water). Lamingo reservoir is far less disturbed. A more detailed study of the reservoirs over a longer period of time is solicited to enable us follow the trends in macroinvertebrate diversity in the system. Some management options that could help reduce human impacts on the reservoirs are suggested.
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Key words: tropical reservoirs, Nigeria, macroinvertebrates, macrozoobenthos, molluscs, arthropods, human interferences

1. Introduction

Macroinvertebrates are animals without backbones. Those that are adapted to aquatic life have representatives among a variety of animal groups that include hydras, molluscs, worms and arthropods. Some of them are large enough to be seen with the naked eye though, in some cases, their detailed characteristics can only be appreciated with the aid of a dissecting microscope or an appropriate magnifying lens. A light microscope may be needed for the identification of smaller animals. Aquatic macroinvertebrates form an important part of aquatic food webs that begins with the primary producers: sunlight is converted to energy by aquatic plants (microalgae and macrophytes), which are then eaten by primary consumers such as snails and mosquito larvae. The latter are eaten by predators higher up the food web. But primary production in a reservoir is believed to be very small. The ecosystem must receive allochthonous organic matter in order to support a diverse community that includes macroinvertebrates. Decomposing leaves and stems from macrophytes (Murkin, 1989; Campeau et al., 1994) and trees (Cuffney and Wallace, 1987; McArthur et al., 1994) are important sources of detritus, as are inputs from riparian habitats and upland run-off (Schleuter, 1986; Muthukrishnan and Palavesam, 1992; Oertli, 1993). Leaf matter and sticks that fall into the water from riparian vegetation or transferred into the system via runoffs and/or wind actions are eaten directly by aquatic macroinvertebrates known as ''shredders'' (Cuffney and Wallace, 1987; McArthur et al., 1994). Examples of shredders include stonefly and caddisfly larvae, which shred or bite soft parts of plant materials for food. Other macroinvertebrates (the ''collectors'') feed mainly on detritus (Kok and Van der Velde, 1994). Examples of collectors include bloodworms (midges) and amphipods. These herbivorous macroinvertebrates are then eaten by predacious carnivores (Maher, 1984; Bennett and Streams, 1986; Van Buskirk, 1989; Blois-Heulin et al., 1990), such as dragonfly larvae, damselfly larvae, diving beetles, tiger beetles, caddis grubs and water mites. Macroinvertebrates, generally, form an essential food source for fish, amphibians, aquatic birds and mammals like platypus (Davis and Christidis, 1997).

Macroinvertebrates, as an integral part of the aquatic ecosystem, are used as indicators of pollution, when testing for the health status of a water body. This is because they are sensitive to different chemical and physical conditions. A change in water quality or characteristics (be it biological, chemical or physical) has the potentials of changing the community structure of macroinvertebrates living in a water body. Essentially, macroinvertebrate community would vary in different water bodies according to water quality, the prevailing biotic components of the system, as well as the degree of human interference. Once familiar with the macroinvertebrate taxa in a particular area, it would be possible to use them to monitor the quality of water in that area (Wallis, 1992). The aim of this study was to investigate macroinvertebrate communities in two tropical reservoirs in Nigeria that are subjected to different levels of human interference, and to provide a preliminary inventory (base-line data) of macroinvertebrate taxa in the systems.

2. Materials and methods

2.1. Study sites

Lamingo and Liberty reservoirs are neighbouring ecosystems, which are located in the biotite granite-rock-strewn Lamingo village in Jos North Local Government Area of Plateau state, Nigeria (see Khan and Ejike, 1984). The catchment area of Lamingo reservoir is composed of plain land with an open field view. There are no trees on the banks of the reservoir, except at the rip-raps of the embankment where shrubs are seen. Sparsely-populated shrubs also dot some other areas of the reservoir's immediate surroundings. There are also grassy landscapes on the reservoir's catchment area. Cattle are driven to the reservoir to quench their thirst. There are no farming activities in the catchment area of Lamingo reservoir. The substrate of the littoral zone is characterized by clayey, sandy surfaces at some locations and silt/mud and small gravels on other locations. The water level of Lamingo reservoir fluctuates according to direct precipitation, runoffs and evaporation rates. There is an outflow point constructed upstream the dam through which excess water flow out into the nearby Liberty reservoir. Liberty Dam, which forms Liberty reservoir, is the biggest of the four dams located in Lamingo village. Farming, silviculture and block-moulding ventures are common sights within the catchment area of Liberty reservoir. Persons that manage these ventures extract water from the reservoir to support their businesses. Like Lamingo reservoir, there are no trees on the banks of the reservoir but patches of grass-covered areas are a common sight. Cattle are also driven the reservoir to drink. The water level also fluctuates with the seasons.

2.2. Parameters sampled and studied

Sampling was carried out on 19/05/2011 and 26/05/2011 for Lamingo reservoir, and on 26/05/2011 and 08/06/2011 for Liberty reservoir. Sampling was performed by wading into the shallower parts of the littoral zone of the two reservoirs. Some chemical and physical parameters of the reservoirs were measured for each sampling date. Both air and water temperatures were taken using a mercury-in-glass thermometer. Water temperature was measured by placing the thermometer horizontally and a few centimeters below the water surface. For pH determination water was collected in two separate plastic bottles, one for each reservoir, and taken to the laboratory for analysis. In the laboratory, a pH meter (Labtech ™) was used to determine the pH of the waters. For the determination of dissolved oxygen water samples were collected in 250 ml stopper bottles. Water samples were collected, and the bottles stopped, under water. 2 ml of $MnSO_4$ and 2 ml of alkaline-iodide sodium azide were immediately added to fix the water samples. Following this step, precipitates formed in the bottles. The fixed water samples were taken to the laboratory for further analysis. In the laboratory, 2 ml of conc. H_2SO_4 was added to the fixed water samples and the bottles gently shaken, procedures which led to the dissolution of the formed precipitates and the formation of a golden yellow solution. Dissolved oxygen was then determined following the Winkler titration method (APHA, 1992) and results registered as parts per million (ppm). For nitrate-nitrogen and phosphate-phosphorus concentrations in the reservoirs, water samples were collected in plastic bottles and taken to the laboratory for nitrate and phosphate contents determination, using the spectrophotometeric method (see AOAC, 1980).

For macroinvertebrate studies, a pond net was used to sample the benthic zone at the shallower parts of the reservoirs, in a shovel- and rake-like manner. Benthic matter (mud, silt, sand, small gravels and detritus as well as associated invertebrates) collected was washed through a vegetable sieve and then through a tea sieve - procedures which made it possible to pick out and sort the macroinvertebrates. Sometimes a magnifying glass was employed to fish the animals among silt, sand grains and minute gravels. The captured animals were put in sample bottles containing 96% ethanol, labelled and taken to the laboratory for further examination. In the laboratory, the organisms were studied under the stereo microscope. The animals were identified to the Family level using taxonomic guides by Fitter and Manuel (1986) and Clifford (1991). The macroinvertebrate family level is viewed by many workers (e.g. Hilsenhoff, 1988; Chessman, 1995; Miserendino and Pizzolón, 1999) as being rapid and sufficient for assessing freshwater quality.

3. Results

3.1. Physico-chemical parameters

The results of the measured physico-chemical parameters, which included air and water temperatures, as well as pH, and concentrations of dissolved oxygen, phosphate-phosphorus and nitrate-nitrogen are presented in Table 1. The least recorded pH for both reservoirs was 7.74, while the highest value of 8.45 was recorded on the first sampling date at Lamingo reservoir. These pH values indicated that the waters of the reservoirs were not acidic. Dissolved oxygen concentrations were about the same for the two sampling dates, for both reservoirs, and showed that both Lamingo and Liberty reservoirs are adequately oxygenated. Generally, nitrate-nitrogen concentrations were comparatively higher in Lamingo reservoir than in Liberty reservoir. Nitrate-nitrogen concentration was, however, very high on the first sampling date in Lamingo reservoir. The mean phosphate-phosphorus concentration was comparatively higher in Lamingo reservoir (mean = 243 µg/L) than in Liberty reservoir (mean = 225 µg/L). At the Lamingo water body air temperatures were slightly higher than those of water for the two sampling dates (1 °C difference on the first date, and 2 °C on the second). Liberty reservoir air temperature was higher than water temperature by 4 °C on the first sampling date. But there was no difference between air and water temperatures on the second sampling date.

Table 1. Observed values of physico-chemical parameters of Lamingo and Liberty reservoirs with sampling dates

Reservoir	Lamingo		Liberty	
Date	19/05/11	26/05/11	26/05/11	08/06/11
pH	8.45	7.74	7.74	7.58
Dissolved 0_2 (ppm)	8.30	8.50	8.20	8.00
Nitrate-N (µg/L)	844.00	62.00	21.90	11.00
Phosphate-P (µg/L)	217.00	269.00	311.00	139.00
Air temperature (°C)	33.00	28.00	30.00	28.00
H_20 temperature (°C)	32.00	26.00	26.00	28.00

3.2. Macroinvertebrates

Table 2 shows a list of the macroinvertebrate taxa recorded in both reservoirs. Lamingo reservoir had more taxa than Liberty reservoir. Out of the 199 animals recorded for the two reservoirs, 80.40 % were recorded in samples collected from Lamingo reservoir (Table 3). A striking observation was that whereas mollucs (gastropods and bivalves) were present in samples collected from Lamingo reservoir, there was no mollusc recorded for Liberty reservoir, during this study. The numerical strengths and the percentages of the various taxa observed in samples collected from both Lamingo and Liberty reservoirs are presented in Table 3. In Lamingo reservoir the tricopterans were the most important (numerous) group. They were followed by the bivalves (Pelecypoda), which were then followed by the chironomids, notonectids, lymnaeids, planorbids, libellulids, cybaeids and the heptageniids, in that order. In Liberty reservoir the chironomids were the most numerous. The chironomids were followed by the gerrids, gomphids and the haliplids, in that order. From the foregoing it could be instructive to assume that macroinvertebrate taxa richness is higher in Lamingo reservoir than in Liberty reservoir. Nevertheless, a longer sampling period that will cover a wider area of the two reservoirs is being planned. The planned work is expected to clearly ascertain the level of macroinvertebrate taxon richness in the two reservoirs.

4. Discussion

4.1. Physico-chemical parameters

4.1.1. Temperature

Temperatures obtained in this study reflect the tropical climate of Jos town and Nigeria as a whole. Normally, the temperatures of tropical zones do not fluctuate much. In other words the difference between low and high temperatures is not large in the tropics, compared to temperate regions where the difference between summer and winter temperatures is quite large. Thus, in a tropical reservoir that holds water permanently throughout the year, temperature effect on biota living in the ecosystem is expected to be very minimal or negligible; rainfall is tipped to be the governing factor affecting the occurrence and distribution of macroinvertebrates in such a water body. This thinking corroborates the reasoning of Wantzen et al. (2006) who noted that tropical regions do not have strong thermal seasonality, but most of them experience some degree of seasonality in rainfall. Rainfall, which shows strong responses to seasonal precipitation, in turn, governs the hydrology, and important ecosystem patterns and processes, as well as patterns of community composition in a freshwater body. We shall see how this plays out in the more detailed studies that are planned for the reservoirs in Lamingo village.

Table 2. Macroinvertebrate taxa observed in Lamingo and Liberty reservoirs during this study

Taxonomic divisions					Reservoir
Phylum:				Mollusca	Lamingo
	Class:			Gastropoda	Lamingo
		Order:		Basematophora	Lamingo
			Family:	Lymnaeidae	Lamingo
			Family:	Planorbidae	Lamingo
	Class:			Pelecypoda	Lamingo
		Order:		Veneroida	Lamingo
			Family:	Sphaeriidae	Lamingo
Phylum:				Arthropoda	Lamingo/Liberty
	Class:			Arachnida	Lamingo
		Order:		Araneae	Lamingo
			Family:	Cybaeidae	Lamingo
	Class:			Insecta	Lamingo/Liberty
		Order:		Coleoptera	Liberty
			Family:	Haliplidae	Liberty
		Order:		Diptera	Lamingo/Liberty
			Family:	Chironomidae	Lamingo/Liberty
		Order:		Ephemeroptera	Lamingo
			Family:	Heptageniidae	Lamingo
		Order:		Hemiptera	Lamingo/Liberty
			Family:	Gerridae	Liberty
			Family:	Notonectidae	Lamingo
		Order:		Odonata	Lamingo/Liberty
			Family:	Gomphidae	Liberty
			Family:	Libellulidae	Lamingo
		Order:		Trichoptera	Lamingo
			Family:	Goeridae	Lamingo

4.1.2. pH

A pH range of 6.5 to 8.2 is optimal for the survival and reproduction of most aquatic biota (www.fivecreeks.org/monitoring/pH.html). The pH values recorded for the water bodies in this study are well within the optimal range for most aquatic biota. An important point, since the reservoirs serve as sources of pipe-borne water for Jos town, to note is that the reservoirs are not acidic. Acidity can cause levels of dangerous trace elements, e.g. aluminium, in surface water drinking sources to increase (see Schecher and Driscoll, 1988; Srinivasan et al., 1999). Although some workers in the field of limnology believe granite will lower the pH to acid levels (see extension.usu.edu/files/publications/publication/NR_WQ_2005-19.pdf), others are of the opinion that granite will not affect the pH of a water body (see http://www.water-research.net/Watershed/pH.htm).

The most significant parameter governing water chemistry parameters seems to be the percentage of open land (cultivated land and/or meadows) in the drainage areas. High percentage leads to high pH, alkalinity, conductivity, and hardness. There are no significant relationships between bedrock geology of drainage areas and lake water chemistry (Nilsson and Håkanson, 1992). But for these inputs one would have been surprised to note that the reservoirs are basic when we consider the geology of the area. As it has been argued that alkalinity is a conservative parameter which does not change readily in well-buffered lakes, and that pH values, on the other hand, may vary both temporally and spatially within a lake (see http://www.waterencyclopedia.com/Hy-La/Lakes-Chemical-Processes.html), a longer period of sampling, which will involve studying a wider section of each reservoir, is definitely needed in order to ascertain how pH varies in the reservoirs, temporally and spatially.

Table 3. Number and percentage of individuals within the various families identified during this study in each reservoir

Class (Order)	**Family**	**Reservoir found**	**Number caught**	**%**
Gastropoda (Basematophora):	Lymnaeidae	Lamingo	11	5.53
	Planorbidae	Lamingo	8	4.02
Pelecypoda (Veneroida):	Sphaeriidae	Lamingo	35	17.59
Arachnida (Araneae):	Cybaeidae	Lamingo	5	2.51
Insecta (Coleoptera):	Haliplidae	Liberty	2	1.00
Insecta (Diptera):	Chironomidae	Lamingo	27	13.57
		Liberty	24	12.06
Insecta (Ephemeroptera):	Heptageniidae	Lamingo	2	1.00
Insecta (Hemiptera):	Gerridae	Liberty	7	3.52
	Notonectidae	Lamingo	21	10.55
Insecta (Odonata):	Gomphidae	Liberty	6	3.02
	Libellulidae	Lamingo	8	4.02
Insecta (Trichoptera):	Goeridae	Lamingo	43	21.61
Grand Total and %			199	100.00
Total and % for Lamingo reservoir			160	80.40
Total and % for Liberty reservoir			39	19.60

4.1.3. Dissolved oxygen

Dissolved oxygen is the most fundamental parameter in water: it is essential to the metabolism of all aerobic, aquatic organisms (Wetzel, 1975). Low levels of dissolved oxygen result in unbalanced ecosystems, biota mortality, odours and other aesthetic nuisances (Thomann and Mueller, 1987). It, thus, influences distribution and abundance of aquatic organisms. Davis (1973) observed that reduction in available oxygen has a marked effect on many physiological, biochemical and behavioural patterns in macroinvertebrates. The dissolved oxygen levels recorded during this research are enough to support a diversity of macroinvertebrate groups. Should the dissolved oxygen level go below 3 ppm, a hypoxic condition may result and which could be hazardous for most aquatic biota. And if the dissolved O_2 level falls below 2 ppm most aquatic biota, including some macroinvertebrates will perish (see www.lamotte.com; Doudoroff and Shumway, 1970; Brungs, 1971; Nebeker, 1972; Gaufin, 1973), except the hardy ones (see Connolly et al., 2004 and references there-in).

4.1.4. Nitrate-nitrogen and phosphate-phosphorus concentrations

These are important nutrients that remotely power the aquatic food webs: nitrate-nitrogen and phosphate-phosphorus are both essential nutrients for microalgal growth. Microalgae are eaten by organisms, including macroinvertebrates, that are higher up the aquatic food web. Nitrate-nitrogen and phosphate-phosphorus are important nutrients to consider in lake management. They play key roles in structuring of aquatic ecosystems. Nitrate is the most stable and most useful form of nitrogenous nutrient sources for algal growth. Hence, we measure nitrate-nitrogen concentration instead of ammonium or nitrite concentrations in aquatic ecosystems. Nitrogen is abundant in the atmosphere in the gaseous state. Some plants, e.g. cyanobacterial species, which are nitrogen fixers, can convert nitrogen gas into the organic nitrogen. Phosphorus (P), on the other hand, has no gaseous phase. Although it is found in rocks, fertilizers, human and animal wastes, as well as in organic matter, P is most often the limiting nutrient in freshwater systems (see Weiskel and Howes, 1992; Manasrah et al., 2006; Ajuzie and Houvenaghel, 2009; http://www.waterencyclopedia.com/Hy-La/Lakes-Chemical-Processes.html); even though it is required in a relatively small proportion by aquatic plants. The limiting role of phosphorus does not necessarily mean that it is in scarce supply. Rather, it refers to its importance in regulating aquatic production. The addition of phosphorus to a phosphorus-limited system results in additional algae or plant growth. For this reason and because phosphorus has no gaseous phase, phosphorus is most often the target of lake management programs addressing excessive enrichment and plant growth (see http://www.waterencyclopedia.com/Hy-La/Lakes-Chemical-Processes.html). Phosphorus contents at 0.139mg/L (or 139 µg/L) and at 0.311mg/L (or 311 µg/L) are quite high. These values make the system to fall under a hypereutrophic water body (see Scheidt et al., 2000; Ruley and Rusch, 2002), at least during the study period. Phosphate is used to determine the trophic condition of a freshwater body because, as already seen, it is the main limiting nutrient in freshwater bodies, while nitrate is important for marine algae (Weiskel and Howes, 1992, Ajuzie and Houvenaghel, 2009). Estuaries according to D'ELIA et al. (1986) show great variation in nutrient limitation.

4.2. Macroinvertebrates

4.2.1. Phylum: Mollusca

4.2.1.1. Class: Gastropoda

Family Lymnaeidae: The family Lymnaeidae is made up of small to large air-breathing freshwater snails (gastropods), belonging to the clade Hydrophila. They do not have true gills and there is no operculum. They take up oxygen directly in the highly vascularized mantle cavity. They exhibit a great diversity of shell shape, but their anatomical traits are extremely homogenous. The whorls are in more than one plane and the shell has an elevated spire. They are grazers that feed on a variety of plant materials, including detritus and microorganisms (e.g. microalgae) attached to substrata (see Clifford, 1991). This family has species that are of economic importance since they are the intermediate hosts of the sheep and cattle liver-fluke, *Fasciola hepatica* (Fitter and Manuel, 1986).

Family Planorbidae: Members of this family are commonly referred to as ram's horn snails (Fitter and Manuel, 1986). Like their lymnaeid counterparts, they are air-breathing animals. They do not have true gills and there is no operculum. They take up oxygen directly in the highly vascularized mantle cavity. They graze on a variety of plant materials and microorganisms attached to substrata (see Clifford, 1991). Many planorbids have coiled shells that are planispiral, i.e. the shell's whorls are in one plane and flat with no elevated spire. Although they carry their shell in a way that makes it appear dextral, their shell, which is carried upside down, is in fact sinistral in coiling. Their foot and head are relatively small when compared to their long thread-like tentacles. According to Clifford (1991) Lymnaeidae and Planorbidae probably attain their greatest numbers and diversity in marshes and shallow ponds having lots of aquatic vegetation. They rarely occur in fast-flowing water bodies (Fitter and Manuel, 1986). During the rainy season the shallow littoral zones of Lamingo reservoir are covered by aquatic vegetation. In the dry season microphytobenthos mats are a common sight on the substratum. The gastropods were sampled from detritus bed in the littoral zone. Most snails require high dissolved oxygen concentrations, so they are seldom found in severely polluted waters or deeper parts of lentic ecosystems (Pennak, 1989). Other factors that can reduce the diversity of snails in a water body are low pH values, heavy metals, pesticides, extreme temperatures, and organic pollution (Harman, 1974). However, both the lymnaeids and the palnorbids are among pulmonates that are more resistant to organic pollution (Last and Whitman, 1999), and to habitat disturbance.

4.2.1.2. Class: Bivalvia (Pelecypoda)

Family Sphaeriidae: This family is made up of small to minute freshwater bivalve molluscs commonly referred-to as pea or fingernail clams. The two valves of the shell are the most conspicuous feature of pelecypods. The two valves interlock with each other by teeth. Left and right valve, anterior and posterior ends, and dorsal and ventral sides are easily determined by noting the teeth. The umbo is dorsal and anterior of centre (Clifford, 1991). Generally, bivalves have only two gills on each side, but the gills are enormously developed. Each gill bears a large number of gill filaments. They are filter-feeders and the gills are very important in feeding. They possess a pair of siphons. One of these is the inhalant tube, the other exhalant. Water containing minute food particles, e.g. organic detritus of various kinds and microalgae (Pennak, 1989), will enter the mantle cavity, via the inhalant siphon. The food particles will adhere to the gill filaments' surfaces before the water leaves through the exhalant siphon. These minute food particles will be concentrated and moulded into a food rope by cilia and mucus. The food ropes will move along grooves formed by the gill filaments and eventually reach the region of the mouth, there is no head as such in bivalves, and then into the gut (Fitter and Manuel, 1986; Clifford, 1991). Sphaeriids could be abundant in all habitats, including isolated pools, water troughs or in interstitial water in gravel deposits (Fitter and Manuel, 1986). Bivalves recorded in this study were captured on sandy/small gravel beds. Some freshwater bivalves are hosts to parasites like flukes, roundworms, and water mites (Last and Whitman, 1999). They are adversely affected by a range of pollutants, including heavy metals, chlorine, urban wastewater effluents, silt, and acid discharges from mines (MCMAHON 1991). They are rated as being quite tolerant of certain natural phenomena and indicative of clean unpolluted waters (Last and Whitman, 1999), although certain sphaeriid species are tolerant of polluted conditions (Fuller, 1974).

4.2.2. Phylum: Arthropoda

4.2.2.1. Class: Arachnida

Family Cybaeidae: This is a fairly small family of spiders associated with the aquatic environment. They are typically medium-sized spiders, which are fully adapted to live in the aquatic ecosystem. Their legs have hairs, which assist them to glide on the water surface without sinking. They are mostly found in the littoral areas of streams with negligible current and shallow lenthic system with emerged vegetation. In the absence of vegetation, they are seen crawling on the shores of the water body and when chased, they dash into the water where they remain afloat. All spiders are predacious, feeding mostly on other invertebrates, including species that transmit parasites, e.g. mosquitoes and their larvae. Some are cannibalistic (Clifford, 1991).

4.2.2.2. Class: Insecta

4.2.2.2.1. Order: Coleoptera

Family Haliplidae: The haliplids are common aquatic coleopterans referred-to as crawling water beetles. They are found in all types of aquatic habitats, being more numerous and diverse in standing water than in running water. Both larvae and adults can be collected from aquatic vegetation of standing waters, such as lakes, ponds and marshes, but some occur in shallow water areas of streams. They may attain up to 4 mm in size. Adults of this family are distinctive because of their greatly expanded coxal plates. They are typically herbivorous, feeding on filamentous algae (Fitter and Manuel, 1986; Last and Whitman, 1999). Both adults and larvae are found mainly on the substratum, although some are active swimmers (Fitter and Manuel, 1986; Clifford, 1991). The two individuals recorded in this study were collected on a bed of detritus, on which they probably feed. Water beetles are more tolerant of environmental extremes than most insects (Roback ,1974). They are considered as being moderately tolerant of certain natural phenomena and indicative of clean unpolluted water bodies (Last and Whitman, 1999).

4.2.2.2.2. Order: Diptera (represented by midges)

Family Chironomidae: Midges have worm-like larvae that can attain up to ca. 60 mm in length. The larvae have visible heads and a pair of prolegs on the pro-thorax, and there might be another pair at the caudal segment, depending on the family. The penultimate segment may bear filamentous gills. They are a cosmopolitan group, whose larvae are found in sediments, some in high numbers. This study recorded individuals belonging to the family Chironomidae. In terms of numbers of species and individuals, chironomids are probably the dominant aquatic family of dipterans. Larvae are found in almost all types of aquatic habitats. Some can withstand low oxygen levels and can live in the oxygen-poor substrata of deep lakes and below sewage outfalls. The larvae of a few species live within aquatic plants, aquatic weeds, and even in the shells of snails. There is one genus, *Symbiocladius,* which is an ectoparasite of mayfly larvae. Chironomid larvae can be very important in aquatic food webs. Some larvae are predacious, others omnivorous, and yet others are detritus feeders (Hilsenhoff, 1991; Schmedtje and Colling, 1996). They are preyed upon by other invertebrates, fish, and birds (Williams and Feltmate, 1992). Chironomids, depending on the species, may have one to several generations a year and some may possibly take two years to complete a generation. Pupal chironomids are found in the same habitat as the larvae and can be very common. The pupal stage is brief. Just like mosquitoes, the adult escapes from the pupal skin at the water surface. The adults, which do not bite, rarely live for more than a week. Adults of many species form large swarms at certain times during the day or just before dusk. These harmless midges, which swarm in great numbers around water margins, can prove a distraction and constant irritation in some places, because their buzzing flight is very reminiscent of their biting cousins (see Fitter and Manuel, 1986; Clifford, 1991).

4.2.2.2.3 Order: Ephemeroptera (Mayflies)

Family Heptageniidae: This is a family of mayflies with two or three long tails. The wings are usually clear or variegated and with prominent venation. Ephemeropterans are common aquatic insects throughout most regions of the world. The name, Ephemeroptera, refers to the very brief adult life span of most species; usually adults live less than three days. Juveniles (nymphs) are found in unpolluted waters of both standing and running waters, on soft, small-particle substratum or found clinging to the substrata such as wood and pebbles. Nevertheless, they achieve their greatest diversity in streams. They are an important food item for fish and larger invertebrates. Hence, they spend most of their lives hidden under stones, among weeds or detritus, or buried in the sediment. They are seldom found in the open water, except when they are about to metamorphose into winged forms. Nymphs are mainly detritivores, but they might eat substantial amounts of algae, especially diatoms; and a few species within Heptageniidae are entirely carnivorous (see Fitter and Manuel, 1986; Clifford, 1991). Generally, ephemeropterans apply a collector–gatherer feeding strategy (Elliot et al., 1988). Mayflies as a group are very important biological indicators of water quality since many species are very susceptible to water pollution or occur in predictable habitat types (McCafferty, 1983).

4.2.2.2.4. Order: Hemiptera (Aquatic bugs represented by the gerrids and notonectids)

Family Gerridae: Species in this family include the water skaters. Their second and third pairs of legs are long and are spread widely. First pair is for capturing prey. Gerrids are found on the surface of both running and standing waters in small groups. They can stride rapidly over the water's surface because of a combination of the water's surface tension and the unwettable hairs on their tarsi. They may attain 17 mm in length (Fitter and Manuel, 1986).

Family Notonectidae: The notonectids are referred-to commonly as back swimmers, for they swim upside down. They swim beneath the water's surface of mainly ponds and lakes, but they are also found in quiet waters of moderate-size to large streams. They break the water's surface with the tip of the abdomen. All hemipterans are predacious, though many genera of the water boatman (Corixidae) are primarily collectors that feed on detritus (Last and Whitman, 1999). Predatory species can attack and feed on relatively larger animals such as copepods, cladocerans, amphipods, mosquitoes and their larvae, mayfly and damselfly nymphs, as well as tadpoles and juvenile fish. Additionally, gerrids can be cannibalistic (see Fitter and Manuel, 1986; Clifford, 1991). Most hemipterans seem to be resistant to predation, possibly due to their characteristic scent glands. However, some are important food items for fish (Last and Whitman, 1999). Water bugs are more tolerant of environmental extremes than most insects, except the water beetles and flies (Roback, 1974). Nevertheless, they are found in unpolluted waters (Last and Whitman, 1999).

4.2.2.2.5. Order: Odonata (represented by dragonflies)

Family Gomphidae: This is a family of dragonflies. Their nymphs are typically short, robust predators with wing pads, hairy bodies, and internal gills. Members may reach up to 30 mm in length (Fitter and Manuel, 1986).

Family Libellulidae: This is yet another family of dragonflies. They have stout, hairy-bodied nymphs with the lower lip (labium) developed into a mask over the lower part of the face. The juveniles are predacious, capturing other aquatic invertebrates with the large labium. When the dragonfly nymph is ready to transform into the adult, it leaves the water and emerges holding on to stems of aquatic macrophytes, a tree trunk, or perching on surfaces of exposed boulders. Thus, they could be seen on plants, among stones and leaf litter or as infaunae (burrowers) on the water bed. Dragonflies are harmless to man. Shortly after metamorphosis, adults will be seen flying and feeding on other flying insects, the adults also being predacious. They diet would include many noxious insects like mosquitoes and biting midges (Fitter and Manuel, 1986, Clifford, 1991). Many species of Libellulidae are very adaptable and tolerant of low dissolved oxygen concentrations or highly eutrophic habitats (McCafferty, 1983). They have been considered indicative of both clean, unpolluted waters and likely severe organic pollution (see Patrick and Palavage, 1994; Last and Whitman, 1999).

4.2.2.2.6. Order: Trichoptera (Caddisflies)

Family Goeridae: Generally, caddisflies larvae have soft, cylindrical body. A characteristic feature of the larvae is that the head, pronotum, and often other parts of the thorax are sclerotized. Other special features include filamentous gills on the abdomen that are variously arranged, as well as a pair of short or moderate anal prologs, each of which is adorned with a sclerotized hook. Members of the family Goeridae are similar in size and shape to several families but have a distinctive mesonotum that distinguishes them from other families. Whereas the anterior sides of the pronotum of some genera of the goerids are extended forward, the anterior sides of the mesonotum are always extended forward. The mesonotum is divided into two or three pairs of separate plates. They do construct their cases with sand grains; with larger pebbles attached to the sides (http://www.epa.gov/bioiweb1/html/caddisflies_goeridae.html). Different caddisfly larvae have different modes of feeding, but they are generally omnivorous, although some of the larger species are carnivorous. Some capture food in nets, others scrape algae or shred leaf litter (see Fitter and Manuel, 1986). Caddisflies are important prey items for fish, amphibians and other predatory invertebrates. They are found mostly in clean streams, ponds and ditches. Larvae of some caddisflies are very sensitive to human disturbance. Perhaps this could tentatively explain why they were absent in the Liberty reservoir (see next paragraph). Caddisflies are very important in Biological monitoring, due to the wide variation in pollution tolerance among species (Hilsenhoff, 1991).

4.3. Probable effects of human interference: The taxonomic groups of Liberty reservoir were fewer than those of Lamingo reservoir. The reason might be because Liberty reservoir suffers a great deal from human pressures like farming within its watershed, extraction of water for crop farming, silviculture, and for block moulding, as well as water tankers driving directly into the reservoir to collect water. The sediment is mostly muddy, which may be hostile to most macroinvertebrates (burying effect). Bivalves, for example, are adversely affected by a number of physical pollutants, including silt (McMahon, 1991). Siltation could be as a result of soil erosion exacerbated by unsustainable farming practices within the drainage basin of most tropical freshwater bodies. Sediment deposition in freshwater ecosystems is a well known phenomenon in the tropics. According to Mol and Ouboter (2004) and Wantzen (2006) many tropical freshwater bodies receive direct inputs of sediments associated with land conversion. In line with this observation, mud is washed down into Liberty reservoir from the surrounding farmlands in the form of loose soil during the rainy season. Lamingo reservoir is far less disturbed and has a comparatively less muddy bottom. Increased sedimentation rates into the littoral zone from numerous anthropogenic activities may affect macroinvetebrates indirectly by damaging habitats and burying food sources (see Batzer and Wissinger, 1996 and the references there-in), or directly by burying them to greater depths. Increased soil erosion and deposition in littoral zones would also prevent the settlement of benthic invertebrates (Wantzen, 2006). Walling and Amos (1999) are of the opinion that the increase of sedimentation can represent a serious damage for freshwater fish, by reducing the supply of oxygen to the hatching eggs, as well as degrading other characteristics of the habitat, which could affect the occurrence of invertebrate prey items. For example, sedimentation can cause clogging of benthic interstitial spaces, which has a negative effect on the occurrence of benthic invertebrates (see Bo et al., 2007).

Herds of cattle are driven to both reservoirs to quench their thirst, but it seems, however, that cattle drivers and their herds visit Liberty reservoir, which is closer to a main road, more frequently than the "hidden" Lamingo reservoir. Livestock drinking from lakes and reservoirs cause an additional stress (trampling effect) on such ecosystems and this has negative impacts on macrozoobenthos. These observations are in agreement with widely held view that high biodiversity (or taxa richness) indicates a site with low human influence. Jorcin and Nogueira (2008) noted that the taxonomic richness and numerical abundance of macroinvertebrate populations are useful tools for a rapid and precise detection of ecosystem alterations. Monitoring freshwater macroinvertebrates, thus, can help in the determination of the health status of water bodies and to identify the ones that are deteriorating due, for example, to human interferences. This will, in turn, make it possible for environmental managers to devise appropriate strategies for remedying a deteriorating or deteriorated freshwater body.

During the sampling period, aquatic macrophytes were not present. Aquatic macrophytes, if present, are expected to provide a more variety of habitats and food resources for the macrozoobenthos and, hence, create room for taxa richness. Aquatic macrophytes are abundant during the rainy season. A longer sampling period, as proposed earlier, which will incorporate both the dry and rainy seasons, will verify the claim that aquatic macrophytes will cause an increase in taxa richness in the reservoirs.

What could be done in order to preserve the reservoirs and their biotas, particularly Liberty reservoir? The following steps could be taken:

a. Cattle visits to the reservoirs and their immediate surroundings should be discouraged.
b. Water tankers must not be driven into the reservoirs in order to extract water from them.
c. Farming within the catchment area of the reservoirs must be discouraged to minimize the amount of loose soil that enters the reservoirs with runoffs. Reduction in the quantity of sediment entering the reservoirs will also reduce the magnitude of negative effects of turbidity.

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