Research Article

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Biodiversity and Community structure of macro-invertebrates in three rivers Likangala, Mulunguzi and the Domasi in the city of ZOMBA-MALAWI: impact of some environmental factors

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Abstract

This study was carried out in the city of Zomba which happen to be the formal capita of Malawi. Three rivers where selected which are: Likangala, Mulunguzi and the Domasi river with each of the rivers having particular characteristics. The Likangala catchment is affected by increasing population which has resulted in urban sprawl. It also originates on Zomba Plateau and flows into Mulunguzi Dam which provides water to Zomba city. The Domasi River collect all the effluent from Domasi market and prison. Generally, 9 sampling stations were studied in 3 streams of the Zomba urban town and a total of 98 taxa were identified, in which 96 were identified to the species or generic level and 2 to the family level. These taxa belong to 3 phyla (Arthropods, Mollusca and Annelids), 4 classes (Crustaceans, Insects, Gastropods and Achaeta), 12 orders and 50 families. Arthropods are the most diversified with 2 classes, 9 orders, 49 families and 92 morphotypes. There are followed by Mollusca with a single class, order, family and 3 morphotyps. The Annelids has just a single family with 2 species. The class of Insects in the most represented with 90 morphotypes divided into 8 orders and 46 families. The Mollusca have 3 species in 2 families and 1 order while the Annelids showed 2 species in a single family. The class of crustaceans had just a single family and species. Of the 8 orders identified in the class of insects, that of Hemiptera is the most represented with 27 taxa and 11 families, it was followed by the Diptera (19 taxa and 7 families), Coleoptera (16 taxa in 7 families), Trichoptera (9 taxa and 9 families), Odonata (8 taxa and 5 families), Ephemeroptera (6 taxa and 5 families) and finally we have the Plecoptera and Aquatic Lepidoptera with just 1 taxon and family each.

Key words: Biodiversity, macroinvertebrates, abiotic factors, three streams, Malawi.

Introduction

African freshwater ecosystems are being increasingly impacted by changes in land use, dam building, pollution, overfishing and invasive species. However, there is still very little understanding of the nature of these impacts on indigenous biodiversity, including species with key ecological roles such as aquatic macroinvertebrates. This study of macroinvertebrates in Zomba-Malawi will take the first steps in assessment and monitoringAfrican freshwaters, while taking steps to understand the role of environmental gradients in promoting the evolution and maintenance of macroinvertebrate diversity Ajeagah *et al* 2013. Insects are the most common macroinvertebrates in aquatic systems, living in water as nymphs or larvae at least until they reach their adult stages. Common insects in aquatic systems include dragonflies, caddisflies, stoneflies, beetles, midges, and mayflies. Others, such as aquatic worms, leeches, and small crustaceans (crayfish and fairy shrimp), live entirely in water. Most species live in the bottom sediments of the waterbody or attached to rocks, vegetation, logs, and sticks. Lifespans range from a few weeks to several years. Macroinvertebrates are most frequently used for biological monitoring, or "biomonitoring," because of their prevalence in aquatic habitats and their differing sensitivities to chemical pollution and physical disturbances. Biomonitoring is the use of organisms to assess the overall quality of their environment or habitat. Because they generally have limited mobility and cannot escape pollution, macroinvertebrates better reflect the long-term water quality of a site compared to a single sample of chemical constituents that only provides a snapshot in time. The aim of this study is to evaluate the Biodiversity and Community structure of macro-invertebrates in three rivers Likangala, Mulunguzi and the Domasi in the city of ZOMBA-MALAWI and assess the relationship to environmental variables.

II- Materials and methods

II- 1- Description of study town

This study was carried out in the city of Zomba which happen to be the formal capita of Malawi. Malawi is a landlocked country in southeast Africa (Figure 1). The population is almost 16 million, as of 2012 (UN Data, 2014) with an area of 118 480 km2, Zomba is a city of 88,314 people (NSO, 2008), situated in the Southern Region of Malawi. The climate in the region is tropical, with annual rainfall of 600-1500 mm/year, with a distinct wet season. The average monthly temperature in June is 11.5°C and the mean maximum temperature in the dry hot season in October is 29.8°C (Chidya *el al*. 2011) The soils are well-drained, medium to fine textured, slightly acidic and moderately deep that generally fall into two main types namely lithols and ferruginous. The geology is varied with its base complex composed of metamorphic rocks of Precambrian origin made up of Upper Jurassic materials (Bloomfield, 1965; ZMUP, 2007). For this study, three rivers where selected which are: Likangala, Mulunguzi and the Domasi river with each of the rivers having particular characteristics as seen on figure 1.

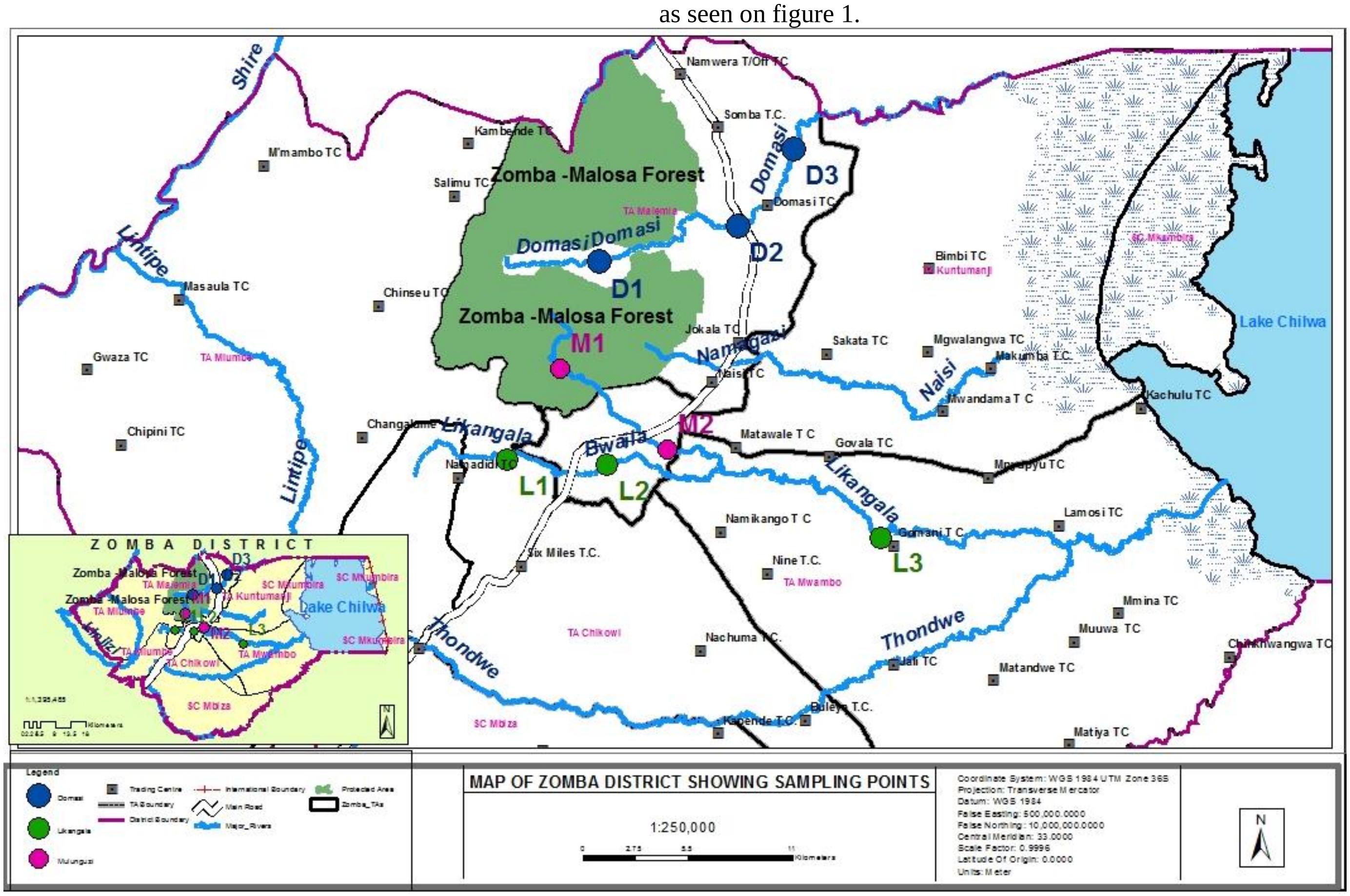

Figure 1: Map of Zomba district showing sampling points

II- 1-1 The Likangala River

The Likangala River is one of the rivers in Malawi that passes through a city (Zomba) and its catchment includes urban, rural and agricultural irrigation areas. The river originates from Zomba Plateau which is threatened with deforestation. Water abstracted from the Likangala River supplies urban areas of Zomba and is used for irrigating a number of tobacco estates and a 450 ha rice scheme which benefits 1 300 farmers. The Likangala River, 15°22′–15°30′ S, 35°15′–35°37′ E, at 631 m to 1 603 m above sea level and with a catchment area of 756 km2 (Chidya *et al*. 2011). The Likangala catchment is affected by increasing population which has resulted in urban sprawl with many new settlements in Zomba city and Thondwe town, the two major urban areas in Zomba District. The river terminates at Lake Chilwa, the second largest lake in Malawi, which is important for its fisheries. Three sampling points where selected from this river base on pollution sources. L1, L2 and L3 as on figure 2.

Sampling point (L1), located upstream of the Zomba mental hospital. Has a number of stone crushers working on the igneous rocks found close to the river. River bank cultivation and sand mining were also observed in this area (figure 2A).

The second point (L2), at Mpondabwino in Zomba city downstream of Zomba Central Hospital, is located in a busy market area. Zomba Central Hospital and Zomba wastewater treatment works in the vicinity of this sampling point are the major polluters. The hospital releases waste, including medical waste, and the treatment works is overloaded by the increased population that it serves, and releases partly-treated waste water into the Likangala River. River bank cultivation is common and sand mining activities were observed in the area. Brick-making from clay, using large quantities of firewood, was also observed along the river. Residents around this sampling point are of middle income class, resident in planned residential areas located next to a low-income area of unplanned settlements. Waste management remains a serious concern here (figure 2B).

L3 is the third sampling point, at Likangala Bridge close to Jali and downstream of Zomba city, has a number of stone crushers working on the igneous rocks found close to the river. River bank cultivation and sand mining were also observed in this area, which is primarily characterized by subsistence agriculture and lies upstream of large agricultural estates. Generally, lower-income residents live in this area and practice farming (figure 2C).

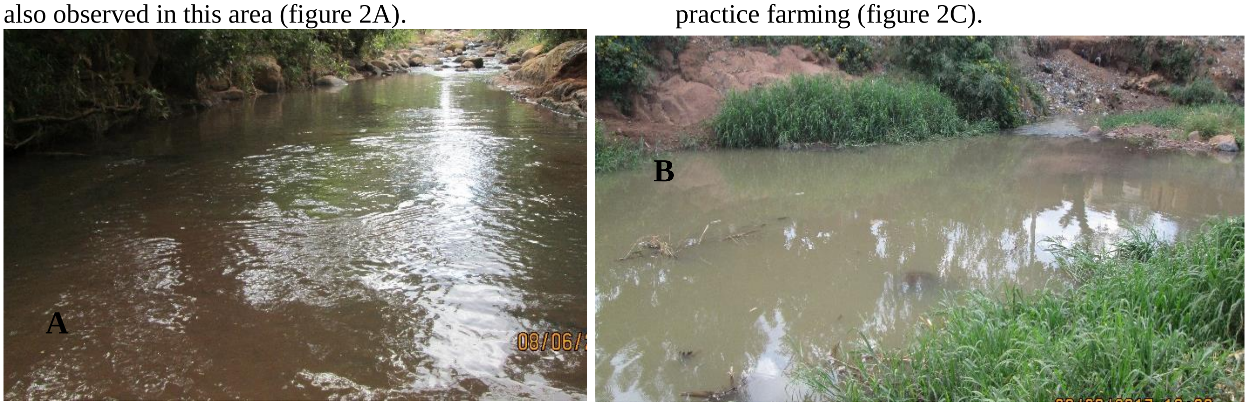

Figure 2: Images of the different sampling points on the Likangala River, L1 (A), L2 (B) and L3 (C).

II- 1-2 Mulunguzi River

Mulunguzi stream, is one of the tributaries of the Likangala downstream and it also originates on Zomba Plateau and flows into Mulunguzi Dam which provides water to Zomba city. Mulunguzi Catchment area covers an area of about 20 km^2 and located between latitudes 15^o 90'S and longitude 35^{o}19' E. The catchment is mainly a commercial pine plantation, which is managed by Forestry Department under Ministry of Forestry and Natural Resources. Other major land uses include silvipastoral, eco-tourism and fish farming. Two points where chosen M1 and M2 (figure 3).

M1 is the first sampling point on the stream located upstream of the Mulunguzi Dam, which provides water to the residents of Zomba. It is fed from Mulunguzi marsh. The area around this sampling point is characterized by mixed species of indigenous and pine plantations with a huge tree canopy along the river. A number of villages and middle income residential areas are located along the slopes of Zomba Mountain (figure 3A).

The second point here is M2 it is situated about 2.5 km downstream of the mulunguzi dam and about 750m to where the stream join with the Likangala. This river goes through several quarters including Matawali, Mukuyu and the military air force base. This point is characterized by sand minding activities and recreational activities like swimming (figure 3B).

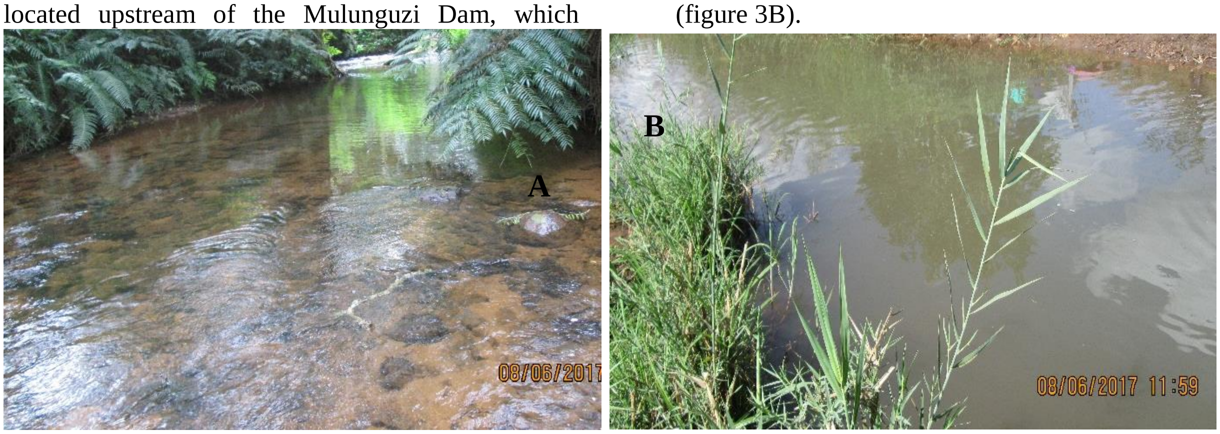

Figure 3: Images of the different sampling points on the Mulunguzi River, M 1 (A) and M 2 (B).

II- 1-3 Donasi River

The Domasi River is situated at the north to the Zomba city and originate at the northern part of the Zomba Plateau. The lower stream is characterized by reeds. Major human activities related to this river system undertaken by local inhabitants include subsistence farming close to the river banks as well as bathing and washing and sand minding. The stream collect all the effluent from Domasi market and prison.

The first sampling point (D1) is located upstream about 1.5 km from the source just behind the kasoga missionaries in the kasoga forest zone, this section of the stream as large rocks and stones and the canopy is made up of tell trees and bamboos. They are agricultural practices along the river banks (figure 4A).

D2 is located downstream about 2 km from D1 around the Domasi Bridge. Here, the water flow over a large rock and is banded by reed and bamboos vegetation. The rock creates favorable conditions for the population to use the area for swimming, washing of domestic items and fishing (figure 4B).

Sampling point D3 is about 5.5 km from D1 just around the Domasi fish cultivation center and below the domasi prison. It drains the waste from the prison and quarters around. This area is the main area of sand minding along the stream and is banded by large and tell tress with bamboos between the trees (figure 4C).

Figure 4: Images of the different sampling points on the Domasi River, D1 (A), D2 (B) and D3 (C).

III-1- RESULTS

III-1-1- Physico-chemical characterization of streams studied

The minimum, maximum, mean and standard deviation of physicochemical parameters measure during the study period are present per sampling stations on Table 1 of the annex. While spato-temporal variations of the physico-chemical parameters are presented here below.

III-1-1-1- Characterization of physical parameters

In the Likangala stream, temperatures varied between 20.3 and 24.9ºC with and mean of 21.9±0.96 and a thermal amplitude of 4ºC. At the mulunguzi stream, we noted a minimum value of 14.8ºC and a maximum of 21.5ºC for a thermal amplitude of 6.7ºC. In Domasi, temperatures ranged between 17 and 22.2ºC for a thermal amplitude of 5.2ºC. No significant difference was notice between the sampling stations (figure 5A).

The mean value of turbidity were generally below 20 NTU in all the sampling stations except for L2 which register 28NTU (figure 5B). Generally, the values where low across the streams (as we noted 19.32±8.6, 10.3±8.34 and 9.93±3.1 for the Likangala, mulunguzi and Domasi streams respectively). This turbidity values show no significant different between the different sampling stations and the different stream

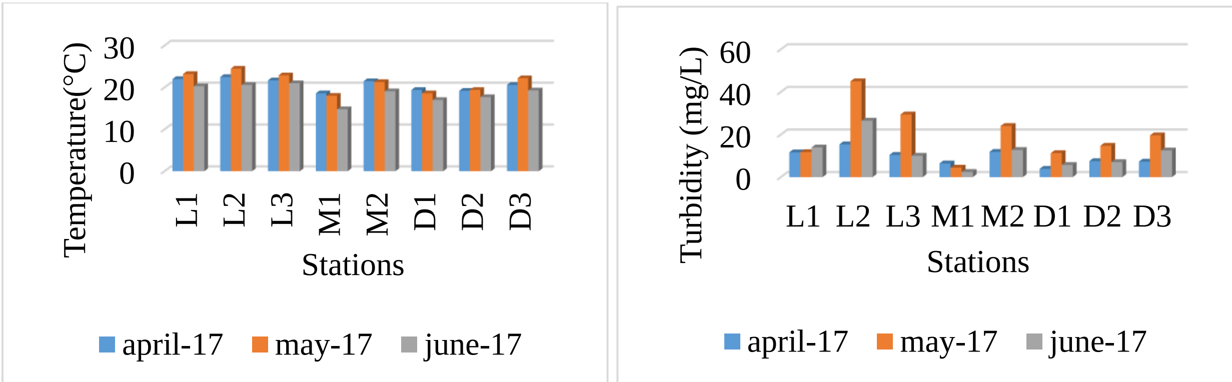

Figure 5: Spatiotemporal variation of (A) Temperature and (B) Turbidityin the different streams studied (L1, L2 and L3 = Likangala, M1 and M2 = Mulunguzi, D1, D2 and D3 = Domasi).

III-1-1-2- Spatial and seasonal variation of chemical parameters

Percentage dissolved Oxygen saturation mean for all the sampling points was greater than 80% in all stations. It varied between 65 to 98% for an overall mean of 91.4±7. All the values stayed above 65% throughout the study period (figure 6A).

As for BOD5, it varied from on station to another. At Likangala, it varied between 3.07 and 6.2 mg/L of oxygen for a mean of 4.87±1.0. This parameter range from 2.26 to 6.05 mg/L and a mean of 4.31±1.86 in the muluguzi while in the Domasi stream, it was between 2.94 and 7.02 mg/L for a mean of 5.23±1.9 (figure 6B).

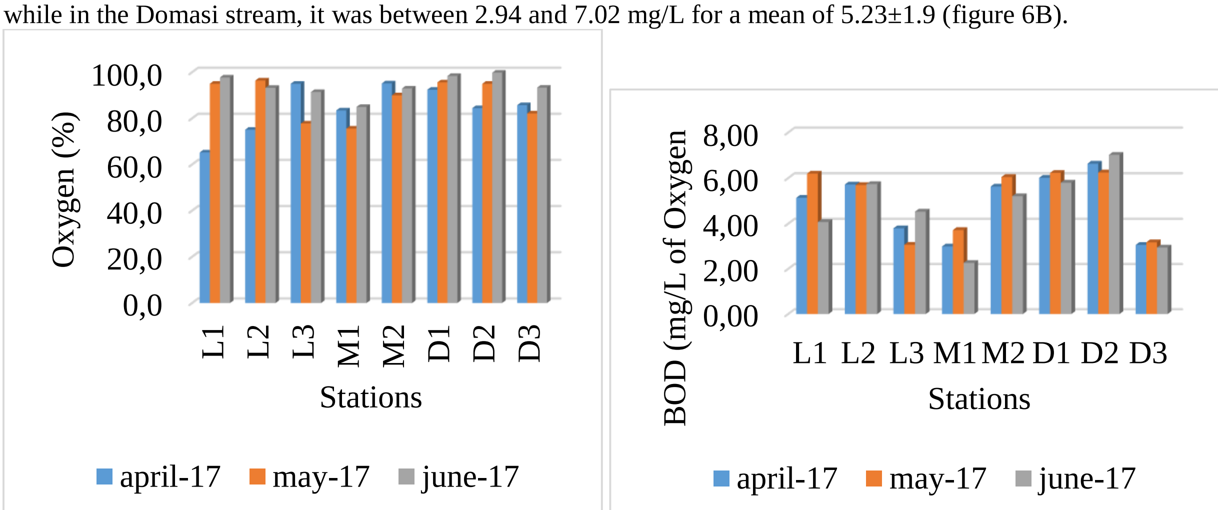

Figure 6: Spatiotemporal variation of (A) Dissolved Oxygen and (B) Oxydability in the different streams studied (L1, L2 and L3 = Likangala, M1 and M2 = Mulunguzi, D1, D2 and D3 = Domasi).

The concentration of Ammonium in the Likangala, the stations L2and L2 varies in a similar manner and are different from L1. The concentration of ammonium is higher in the station L3 with a mean of 2.13±3.16 mg/L (figure 7A). No significant difference was observed among these stations ($P < 0.5$). Contrarily to the Likangala, the concentration increased from upstream to downstream in mulunguzi with means of 2.77±4.3 and 3.5±5.5 mg/L for m1 and m2 respectively. In Domasi stream, the concentration of ammonium lies between 0.05 and 11.14 mg/L for a nean of 5.22±5.1 with the lowest value (0.05 mg/L) was obtained at D1 and the highest at D3 (figure 7A).

The concentration of nitrate in the Likangala varied between 0.12 to 0.37 mg/L for the station L1, from 0.39 to 1.32 mg/L for the station L2 and between 0.3 to 1.13 mg/L at L3 (figure 7B). Throughout the study period, the concentration of nitrate showed no significant different between the stations of Likangala stream. With mean values of 0.71±0.42 and 0.14±0.0.05 respectively obtained for m1 and m2 nitrate concentration are generally lower in the mulunguzi than in the Likangala stream. While in the Domasi stream, the concentration of nitrate fluctuate between 0.01 and 0.35 mg/L statistically, no significant difference was observed between the different sampling points of the stream studied. The mean value of nitrate concentration in the stream oscillate around 0.14±1.07.

The levels of orthophosphates in the three streams did not vary significantly from one station to another during the study period. Throughout the study perod, the values ranged between 0.03 and 0.5 mg/L and noon of the stations show a value higher than the 0.5 mg/L. The mean levels of orthophosphates in the different streams are 0.2±0.25 mg/L, 0.7 ±0.02 mg/L and 0.06±0.02 mg/L obtain in the Likangala, mulunguzi and Domasi streams respectively (figure 7C)

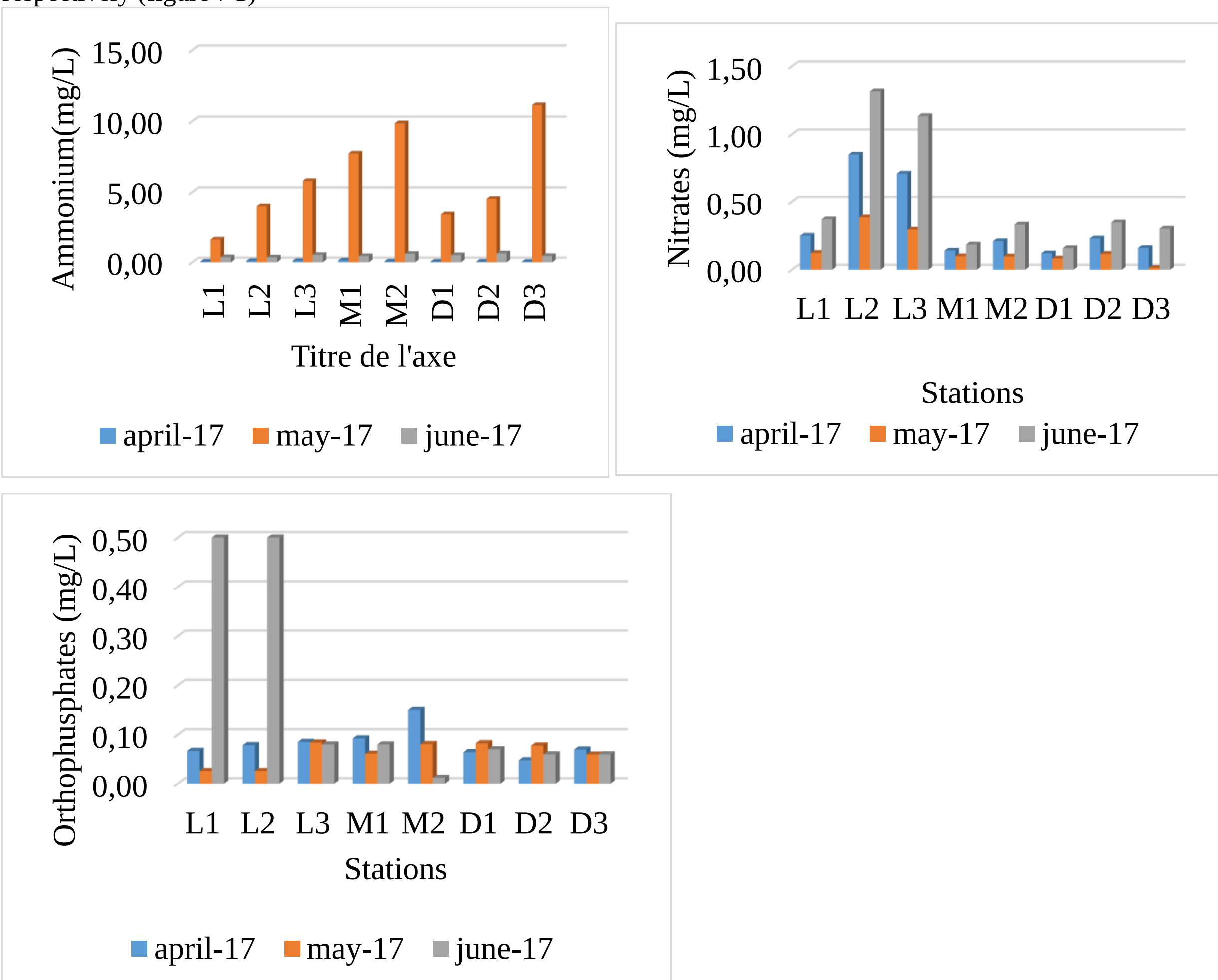

Figure 7: Spatiotemporal variation of (A) Ammonium, (B) Nitrates and (C) Orthophusphates in the different streams studied (L1, L2 and L3 = Likangala, M1 and M2 = Mulunguzi, D1, D2 and D3 = Domasi).

The values of pH in the mufueh, Furmuki and mankon generally vary between 6.8 and 8 CU with most of the values been around the neural point (figure 8A). The mean values of pH 7.88±0.12 (Likangala), 7.47±0.47 (mulunguzi) and 7.79±0.28 (Domasi) shows that this waters are neutral.

Electrical conductivity in the waters of Likangala varied between 8 and 103µS/cm for a mean of 39±54. L2 of the stream recorded the highest value (103 µS/cm) during the study period. At the mulunguzi, the values ranged between 4 and 28 µS/cm for a mean of 9.67±6.6 µS/cm. in Domasi stream, Electrical conductivity varied ranged between 4 and 53 µS/cm and a nean of 14.11±9.35 µS/cm. the highest value (53 µS/cm) for this stream was recorded at D3 (figure 8B)

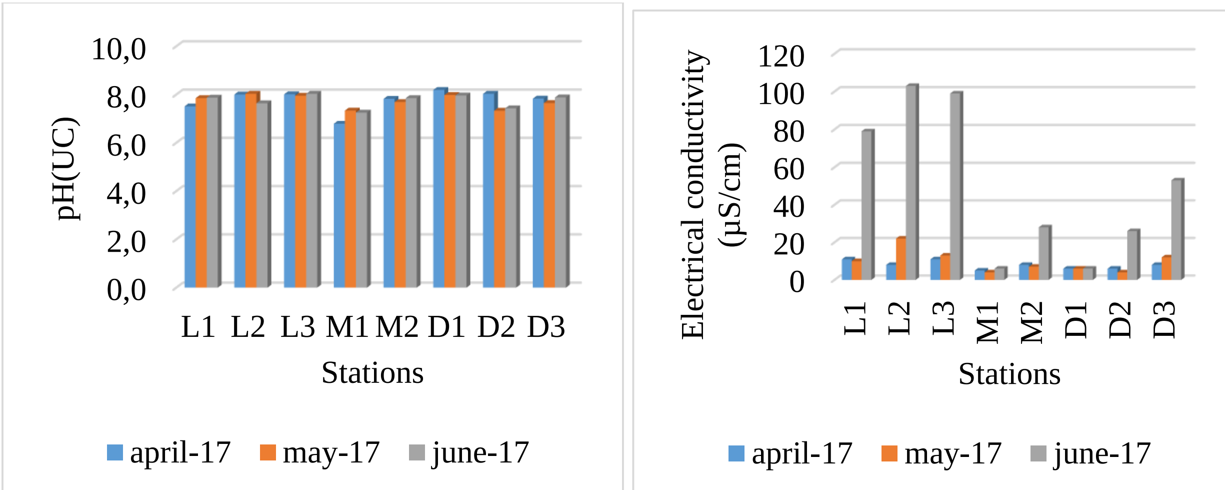

Figure 8: Spatiotemporal variation of (A) pH, and (B) Electrical conductivity in the different streams studied (L1, L2 and L3 = Likangala, M1 and M2 = Mulunguzi, D1, D2 and D3 = Domasi).

III-1-2 Community structure of benthic macro invertebrates sampled in Zomba, Malawi

III-1-2-1 Diversity and distribution of taxa

Generally, 9 sampling stations were studied in 3 streams of the Zomba urban town and a total of 98 taxa were inventorated, in which 96 were identified to the species or generic level and 2 to the family level (Table 1). These taxa belong to 3 phyla (Arthropods, Mollusca and Annelids), 4 classes (Crustaceans, Insects, Gastropods and Achaeta), 12 orders and 50 families. Arthropods are the most diversified with 2 classes, 9 orders, 49 families and 92 morphotypes. There are followed by Mollusca with a single class, order, family and 3 morphotyps. The Annelids has just a single family with 2 species.

The class of Insects in the most represented with 90 morphotypes divided into 8 orders and 46 families. The Mollusca have 3 species in 2 families and 1 order while the Annelids showed 2 species in a single family. The class of crustaceans had just a single family and species.

Of the 8 orders identified in the class of insects, that of Hemiptera is the most represented with 27 taxa and 11 families, it was followed by the Diptera (19 taxa and 7 families), Coleoptera (16 taxa in 7 families), Trichoptera (9 taxa and 9 families), Odonata (8 taxa and 5 families), Ephemeroptera (6 taxa and 5 families) and finally we have the Plecoptera and Aquatic Lepidoptera with just 1 taxon and family each.

The families Gerridae (13), Chironomidae (13), Hydrophilidae (5), Dytisidae (4), Libellulidae and Gyrinidae (3) has the highest taxonomic richness while the rest came with 2 or 1 taxon each.

Throughout the study period, groups like the Annlides, Mollusca, Gerridae, crustacen and Chironomus were only found at the Likangala stream while the Aquatic Lepidoptera were only seen at the Domasi stream.

Table 1: List of of benthic macroinvertebrates recorded in the different sampling stations in zomba throughout the study period *(the code L1, L2 L3, m1, m2, D1,D2, and D3 represent the sampling stations)*

Phylum	Class	Order	Family	Genus	Species	Likangala			Mulunguzi		Domasi		
						L1	L2	L3	M1	M2	D1	D2	D3
Anthropoda	Malacostraca	Decapoda	Potamolidae			2	1	1					
	Insecta	Aquatic Lepidoptera	Grambidae	Synclita	Synclita sp	0	0	0				1	
		Coleoptera	Staphylinidae	Bledius	Bledius sp			0			2	0	
			Gyrinidae	Gyretes	Gyretes sp	5	3	0	2		17	3	2
				Aulonogyrus	Aulonogyrus sp	0	0	0	0		1	0	0
				Gyrinus	Gyrinus sp	4	1	0	1		6	0	0

			Hydrophilidae	Helobata	sp	2	0	1	1	1	0	0	0
				Helophorus	sp	0	0	0	0	0	0	0	1
				Hydrobiomorpha	sp	0	0	1	0	1	0	0	0
				Enochrus	sp	0	0	0	2	0	0	0	0
				Derallus	sp	2	0	0	2	1	0	0	0
			Dytiscidae	Acilius	sp	0	1	2	4	0	0	0	0
				Celina	sp	0	0	0	0	0	0	0	1
				Laccophilus	sp	15	0	2	2	1	0	0	10
				Ilybius	sp	0	0	1	2	0	0	0	0
			Georissidae	Georissue	sp	0	0	0	0	0	0	1	0
			Salpingidae	Aegilites	sp	0	0	0	0	0	1	0	4
			Elmidae	Lara	sp	2	0	8	0	6	1	3	6
		Odonata	Libellulidae	Pantala	*P. falvesceus*	8	4	4	4	3	12	22	4
				Macrothemis	sp	0	0	1	6	0	0	0	0
				Orthemis	sp	3	11	0	1	7	0	2	0
			Gomphidae	Hagenius	sp	0	0	0	3	2	3	0	0
				Progomphus	sp	1	4	0	1	2	0	3	2
			Coenagrionidae	Nehalennia	*N. spaciosa*	2	0	1	3	1	2	5	2
			Calopterygidae	Caropteryx	*C. maculata*	73	80	105	18	16	4	86	45
				Hetaerina	*H. titia*	28	74	101	0	17	2	51	37
		Hemiptera	Gerridae	Pleiobates	*sp*	0	1	0	0	0	0	0	0
				Limnoporus	*L. stal*	2	1	0	0	0	0	0	0
				Limnogonus	sp	0	2	0	0	0	0	0	0
				Ventidius	*V. modulatus*	12	0	0	0	5	0	0	2
					V. malayensis	12	0	1	1	0	0	1	9
				Aquarius	*A. adelaidis*	0	2	0	0	0	0	1	1
					A. remigis	0	2	0	0	0	0	0	0
				Metrocoris	*M. nigrofasciutus*	2	0	0	0	0	0	0	0
				Limnometra	*L. ciliata*	0	0	0	0	0	0	0	1
					L. matsudai	0	0	1	0	0	0	0	0
				Aselepios	sp	0	0	0	0	0	0	1	0
				Rheumatogonus	sp	0	12	0	0	0	0	0	0
				Trepobates	sp	0	1	0	0	0	0	0	0
			Corixidae	Micronecta	*M. kirkaldy*	1	0	0	0	0	0	0	0
					M. ludibunda	0	0	1	0	2	5	0	0

				Hebridae	Lipogomphus	*L. berg*	11	4	20	6	3	9	5	5
				Macroveliidae	Macrovelia	*M. hornii Uhler*	0	2	0	0	0	0	0	0
				Veliidae	Steinovelia	*sp*	0	0	6	0	0	0	0	0
					Rhagovelia	*R. mayr*	79	13	30	70	50	80	53	90
				Nepidae	Nepa	sp	0	3	1	1	0	0	0	0
					Ranatra	*R. fabricius*	0	1	4	0	1	0	0	0
				Belostomatidae	Belostoma	*B. latreille*	3	3	18	7	7	0	2	15
				Hungerford	Graptocorixa	sp	2	1	0	0	0	0	0	0
				Notonectidae	Notonecta	*N. Linnaeus*	11	1	5	0	0	0	0	2
				Hydrometridae	Hydrometra	*H. australisay*	6	0	0	0	0	1	0	5
				Naucoridae	Pelocoris	*P. stal*	0	0	4	6	0	0	0	4
			Ephimenoptera	Caenidae	Caenis	sp	1	3	38	0	4	0	18	21
					Brachycerus	sp	2	0	28	0	2	0	16	7
				Siphlonuridae	Siphlonurus	sp	0	2	25	0	0	16	9	14
				Potamanthidae	Potamanthus	sp	0	0	0	0	0	4	0	0
				Baetidae	Acentrella	*A. sinaica*	4	22	97	6	14	86	50	72
				Heptageniidae	Ecdyonuru	*sp*	0	0	0	0	0	0	6	0
			Trichoptera	Hydroptilidae	Palaeagapetus	*sp*	0	0	9	0	0	0	0	0
				Glossosomatidae	Agapetus	*sp*	0	0	0	1	0	0	0	0
				Lepidostomatidae	Theliopsche	*sp*	0	0	1	9	0	0	0	0
				Phryganeidae	Phryganus	sp	0	0	0	1	0	0	0	0
				Brachycentridae	Brachycentrus	sp	4	0	1	4	0	0	0	0
				Goeridae	Goeracea	sp	0	0	0	0	0	3	0	0
				Sericostomatidae	Agarodes	sp	0	0	0	0	0	2	0	0
				Philopotamidae	Chimarra	sp	0	0	0	2	0	0	0	1
				Hydropsychidae	Hydropsyche	sp	2	0	13	3	28	2	42	16
			Plecoptera	Pteronarcyridae	Pteromecella	*P. banks*	0	0	0	0	0	1	0	0
			Diptera	Ephydridae	Allotrichoma	sp	0	2	0	0	0	0	0	0
				Empididae	Hemerodrominae	sp	0	0	0	0	0	1	0	0

			Sciomyzidae	Tetanocera	sp	0	0	0	1	0	1	0	0
			Syrphidae	Eristalis	*E. tenax*	0	1	0	0	0	0	0	0
			Tipulidae	Hexatoma	sp	0	0	0	0	0	0	1	1
			Simullidae	Simulium	sp	3	0	2	1	0	1	6	2
			Chironomidae	Chironomous	*C. riparious*	0	37	0	0	0	0	0	0
					C. staegeri	0	19	4	0	0	0	0	0
					C. stigmaterus	0	18	3	2	2	0	0	0
					sp	0	16	0	0	0	0	0	0
				Cryptochironomous	*sp*	0	0	1	0	0	1	1	0
				Ablabesmyia	*A. peleensis*	1	4	4	0	0	0	0	0
				Bryophaenocladius	*sp*	0	0	3	0	0	1	4	0
				Saetheria	*S.tylus*	0	0	1	0	0	0	0	0
				Djalmabatista	*D. pulchra*	0	0	0	0	0	0	0	2
				Denopelopia	*D. atria*	1	0	0	0	0	0	0	0
				Polypedilum	*P. beckae*	0	2	2	0	12	0	0	0
					P. illinoense	0	4	3	0	1	1	2	4
				Radotanypus	*R. florens*	1	3	4	5	6	9	2	4
Annelida	Achaeta	Rhynchobdellidae	Glossiphoniidae	Haementeria	*H. Costata*	0	15	0	0	0	0	0	0
				Helobdella	*H. stagnalis*	0	15	0	0	0	0	0	0
Mollusca	Gastropoda	Basommatophora	Physidae	Petrophysa	*P. zionis*	1	0	0	0	0	0	0	0
				Sibirenauta	*sp*	0	1	0	0	0	0	0	0
			Hydrobiidae	Rhapinema	*R. dacryon*	0	1	0	0	0	0	0	0
Total	4	12	50	83	98	308	393	558	178	195	275	397	392

III-1-2-2 Distribution of the taxa in the different sampling stations.

III-1-2-2-1 Likangala stream

The likangala stream had the highest taxonomic richness with a total of 68 species belonging to 33 families, 9 orders, 4 classes (Crustacean, Insects, Achaeta and Gastropods) and 3 phyla (Arthropods, Annelds and Mollusca) as on table 2. The class of Insects dominated with 6 orders, 29 families and 26 species. This class was followed by that of Gastropods with a single order, 2 families and 3 species. The class of Annelids had 1 order, family and 2 species while the crustaceans had just and 1 species and family. The order of Hemiptera register the greatest specific richness with 11 species, followed by Diptera (10 species), coleopteran (7 species) the rest of orders had 6 and less species.

At the first sampling point of this stream (L1), we registered 36 species in 25 families, 8 orders, 3 classes and 2 phyla. The population is dominated by Insects with 6 orders, 23 families and 33 morphotypes. The order of Hemiptera was the most diversified with 11 taxa, coleopteran (7 taxa), odonata (6 taxa), diptera, ephemeroptera and trichoptera had 4, 3 and 2 tax respectively.

Looking at the second station located midstream (L2), 23 families and 41 morphotyes were identified still Insects were the most represented with 5 orders, 19 families and 37 taxa there were followed by molluse with 1 orders, 2 families and 2 taxa. The Annelids and crustaceans both had 1 order, family and 2 taxa. The Order of Hemeptera dominated with 15 species, Diptera (10 species), Odonata (5 species) and the others had less than 5 species. It should be noted that, this is the only sampling points which had all the 4 classes and 3 phyla identified in the work. It was the most diversified and most abundant. It was the only point in which Annelids where recorded.

As for L3, it had just a single phyla, 2 classes (Crustaceans and Insects), 7 orders, 24 families and 42 morphotyes. The class of insected dominated with 6 orders, 23 families and 41 taxa, the crustaceans had just 1 family and taxon. Hemiptera were the most diversified with 11 species, diptera (10) coleopteran (6 species), odonata and ephemeroptera both had 5 species and trichoptera with 4 species.

Table 2: List of of benthic macroinvertebrates recorded in the different sampling stations of Likangala river zomba throughout the study period *(the code L1, L2 L3, represent the sampling stations)*

Phylum	**Class**	**Order**	**Family**	**Genus**	**Species**	Likangala		
						L1	L2	L3
Anthropoda	Malacostraca	Decapoda	Potamolidae			2	1	1
	Insecta	Coleoptera	Gyrinidae	Gyretes	sp	5	3	0
				Gyrinus	sp	4	1	0
			Hydrophilidae	Helobata	sp	2	0	1
				Hydrobiomorpha	sp	0	0	1
				Derallus	sp	2	0	0
			Dytiscidae	Acilius	sp	0	1	2
				Laccophilus	sp	15	0	2
				Ilybius	sp	0	0	1
			Elmidae	Lara	sp	2	0	8
		Odonata	Libellulidae	Pantala	*P. falvesceus*	8	4	4
				Macrothemis	sp	0	0	1
				Orthemis	sp	3	11	0
			Coenagrionidae	Nehalennia	*N. spaciosa*	2	0	1
			Calopterygidae	Caropteryx	*C. maculata*	73	80	105
				Hetaerina	*H. titia*	28	74	101
			Gomphidae	Progomphus	sp	1	4	0
		Hemiptera	Gerridae	Pleiobates	sp	0	1	0
				Limnoporus	*L. stal*	2	1	0
				Limnogonus	*sp*	0	2	0
				Ventidius	*V. modulatus*	12	0	0
					V. malayensis	12	0	1
				Aquarius	*A. adelaidis*	0	2	0
					A. remigis	0	2	0
				Metrocoris	*M. nigrofasciutus*	2	0	0
				Limnometra	*L. matsudai*	0	0	1
				Rheumatogonus	*sp*	0	12	0
				Trepobates	*sp*	0	1	0
			Corixidae	Micronecta	*M. kirkaldy*	1	0	0
					M. ludibunda	0	0	1
			Hebridae	Lipogomphus	*L. berg*	11	4	20
			Macroveliidae	Macrovelia	*M. hornii Uhler*	0	2	0
			Veliidae	Steinovelia	*sp*	0	0	6
				Rhagovelia	*R. mayr*	79	13	30

			Nepidae	Nepa	*sp*	0	3	1
				Ranatra	*R. fabricius*	0	1	4
			Belostomatidae	Belostoma	*B. latreille*	3	3	18
			Hungerford	Graptocorixa	*sp*	2	1	0
			Notonectidae	Notonecta	*N. Linnaeus*	11	1	5
			Hydrometridae	Hydrometra	*H. australisay*	6	0	0
			Naucoridae	Pelocoris	*P. stal*	0	0	4
		Ephimenoptera	Caenidae	Caenis	sp	1	3	38
				Brachycerus	sp	2	0	28
			Siphlonuridae	Siphlonurus	sp	0	2	25
			Baetidae	Acentrella	*A. sinaica*	4	22	97
		Trichoptera	Hydroptilidae	Palaeagapetus	sp	0	0	9
			Lepidostomatidae	Theliopsche	sp	0	0	1
			Brachycentridae	Brachycentrus	sp	4	0	1
			Hydropsychidae	Hydropsyche	sp	2	0	13
		Diptera	Ephydridae	Allotrichoma	sp	0	2	0
			Syrphidae	Eristalis	*E. tenax*	0	1	0
			Simullidae	Simulium	*sp*	3	0	2
			Chironomidae	Chironomous	*C. riparious*	0	37	0
					C. staegeri	0	19	4
					C. stigmaterus	0	18	3
					sp	0	16	0
				Cryptochironomous	sp	0	0	1
				Ablabesmyia	*A. peleensis*	1	4	4
				Bryophaenocladius	*sp*	0	0	3
				Saetheria	*S.tylus*	0	0	1
				Denopelopia	*D. atria*	1	0	0
				Polypedilum	*P. beckae*	0	2	2
					P. illinoense	0	4	3
				Radotanypus	*R. florens*	1	3	4
Annelida	Achaeta	Rhynchobdellidae	Glossiphoniidae	Haementeria	*H. Costata*	0	15	0
				Helobdella	*H. stagnalis*	0	15	0
Mollusca	Gastropoda	Basommatophora	Physidae	Petrophysa (physella)	*P. zionis*	1	0	0
				Sibirenauta	sp	0	1	0
			Hydrobiidae	Rhapinema	*R. dacryon*	0	1	0
Total	4	9	33	61	68	308	393	558

III-1-2-2-2 Mulunguzi stream

In this stream, which flows from te zomba forest into the town, 44 morphotypes were identified belonging to 28 families, 6 orders and a single class (Insecta) and phylum (Arthropods) (Table 3). Only the class of insects was represented in the stream and the order of Coleoptera was the most diversified with 8 taxa and 3 families it was followed by Odonata (7 taxa, 5 families), trichoptera and hemiptera were next with 6 taxa, 5 families.

At the first point M1, we noted 32 taxa divided into 23 families, 6 orders, 1 class and phylum. The population was dominated by coleopteran 8 specie, odoata 7 species, hemiptera and trichoptera both had 6 species while the dipteran had just 4 species which was mostly of the chironomidae family.

The M2 was not too different from M1 despite the fact that, this second point was located about 3 kilometers away from the first. Here, we recorded 26 taxa belonging to 17 families, 6 orders, 1 class (Insects) and phylum

(Arthropods). This community was dominated by Odonata (7 species), Hemiptera (6 species), coleopteran, diptera, ephemeroptera and trichoptera respectively had 5, 4, 3 and 1 species.

Table 3: List of of benthic macroinvertebrates recorded in the different sampling stations of mulunguzi river in zomba throughout the study period *(the code m1, m2, represent the sampling stations)*

Phylum	**Class**	**Order**	**Family**	**Genus**	**Species**	Mulunguzi	
						M1	M2
Anthropoda	Insecta	Coleoptera	Gyrinidae	Gyretes	sp	2	0
				Gyrinus	sp	1	0
			Hydrophilidae	Helobata	sp	1	1
				Hydrobiomorpha	sp	0	1
				Enochrus	sp	2	0
				Derallus	sp	2	1
			Dytiscidae	Acilius	sp	4	0
				Laccophilus	sp	2	1
				Ilybius	sp	2	0
			Elmidae	Lara	sp	0	6
		Odonata	Libellulidae	Pantala	P. falvesceus	4	3
				Macrothemis	sp	6	0
				Orthemis	sp	1	7
			Gomphidae	Hagenius	sp	3	2
				Progomphus	sp	1	2
			Coenagrionidae	Nehalennia	*N. spaciosa*	3	1
			Calopterygidae	Caropteryx	*C. maculata*	18	16
				Hetaerina	*H. titia*	0	17
		Hemiptera	Gerridae	Ventidius	*V. modulatus*	0	5
					V. malayensis	1	0
			Corixidae		*M. ludibunda*	0	2
			Hebridae	Lipogomphus	*L. berg*	6	3
				Rhagovelia	*R. mayr*	70	50
			Nepidae	Nepa	*sp*	1	0
				Ranatra	*R. fabricius*	0	1
			Belostomatidae	Belostoma	*B. latreille*	7	7
			Naucoridae	Pelocoris	*P. stal*	6	0
		Ephimenoptera	Caenidae	Caenis	*sp*	0	4
				Brachycerus	*sp*	0	2
			Baetidae	Acentrella	*A. sinaica*	6	14
		Trichoptera	Glossosomatidae	Agapetus	sp	1	0
			Lepidostomatidae	Theliopsche	sp	9	0
			Phryganeidae	Phryganus	sp	1	0
			Brachycentridae	Brachycentrus	sp	4	0
			Goeridae	Goeracea	sp	0	0
			Sericostomatidae	Agarodes	sp	0	0
			Philopotamidae	Chimarra	sp	2	0
			Hydropsychidae	Hydropsyche	sp	3	28
		Diptera	Sciomyzidae	Tetanocera	sp	1	0
			Simullidae	Simulium	sp	1	0
			Chironomidae	Chironomus	*C. stigmaterus*	2	2
				Polypedilum	*P. beckae*	0	12
					P. illinoense	0	1
				Radotanypus	*R. florens*	5	6

	1	6	28	42	46	178	195

III-1-2-2-3 Domasi stream

The Domasi stream and all its affluent had a low taxonomic richness with 50 morphotypes registered belonging to 35 families, 8 orders, 1 class (Insects) and a single phylum (Arthropods) as noted on Table 4 below. This class was dominated by the order Hemiptera with 10 taxa, Diptera (7 taxa), coleopteran and odonata with 6 taxa while the others had 5 and less than 5 taxa.

At the first sampling point upstream (D1), we had 29 taxa divided into 23 families and 7 orders. Here, the population was dominated by Dipterans which had 7 species and 4 families, Coleoptera (6 taxa and 4 families), Odonata (5 taxa, 4 families) while Hemiptera, Ephimeroptera, Trichoptera and Plecoptera had 4, 3, 3 and 1 species respectively. The species *Radotanypus florens* was particularly abundant in the sampling station.

Moving down to the second point midstream (D2), a total of 28 taxa were identified into 20 families and 7 orders. Unlike the first station, the community here was co-dominated by Odonata, Diptera and Hemiptera with 6 species each. This was followed by Ehpimeroptera (5 taxa), coleopteran (3 taxa), trichoptera and Aquatic Lepidoptera with 1 species each. This station had just one specie of the trichoptera which is Hydropsyche sp.

As for the third point (D3) we recorded the highest taxonomic richness for this whole stream, 32 taxa in 24 families and 6 orders. The Hemiptera were the most diversified with 10 species, Coleoptera (6 species), Odonata and Diptera with 5 species each while the Ephimiroptera came with 4 and lastly Tricoptera with 2 species.

Table 3: List of of benthic macroinvertebrates recorded in the different sampling stations of Domasi river in zomba throughout the study period *(the code D1, D2, D3 represent the sampling stations)*

Phylum	Class	Order	Family	Genus	Species	Domasi		
						D1	D2	D3
Anthropoda	Insecta	Aquatic Lepidoptera	Grambidae	Synclita	sp	0	1	0
		Coleoptera	Staphyliridae	Bledius	sp	2	0	0
			Gyrinidae	Gyretes	sp	17	3	2
				Aulonogyrus	sp	1	0	0
				Gyrinus	sp	6	0	0
			Hydrophilidae	Helophorus	sp	0	0	1
			Dytiscidae	Celina	sp	0	0	1
				Laccophilus	sp	0	0	10
			Georissidae	Georissue	sp	0	1	0
			Salpingidae	Aegilites	sp	1	0	4
			Elmidae	Lara	sp	1	3	6
		Odonata	Libellulidae	Pantala	*P. falvesceus*	12	22	4
				Orthemis	sp	0	2	0
			Gomphidae	Hagenius	sp	3	0	0
				Progomphus	sp	0	3	2
			Coenagrionidae	Nehalennia	*N. spaciosa*	2	5	2
			Calopterygidae	Caropteryx	*C. maculata*	4	86	45
				Hetaerina	*H. titia*	2	51	37
		Hemiptera	Gerridae	Ventidius	*V. modulatus*	0	0	2
					V. malayensis	0	1	9
				Aquarius	*A. adelaidis*	0	1	1
				Limnometra	*L. ciliata*	0	0	1
				Aselepios	*sp*	0	1	0
				Micronecta	*M. ludibunda*	5	0	0
			Hebridae	Lipogomphus	*L. berg*	9	5	5
			Veliidae	Rhagovelia	*R. mayr*	80	53	90
			Belostomatidae	Belostoma	*B. latreille*	0	2	15

			Notonectidae	Notonecta	*N. Linnaeus*	0	0	2
			Hydrometridae	Hydrometra	*H. australisay*	1	0	5
			Naucoridae	Pelocoris	*P. stal*	0	0	4
		Ephimenoptera	Caenidae	Caenis	sp	0	18	21
				Brachycerus	sp	0	16	7
			Siphlonuridae	Siphlonurus	sp	16	9	14
			Potamanthidae	Potamanthus	sp	4	0	0
			Baetidae	Acentrella	*A. sinaica*	86	50	72
			Heptageniidae	Ecdyonuru	sp	0	6	0
		Trichoptera	Goeridae	Goeracea	sp	3	0	0
			Sericostomatidae	Agarodes	sp	2	0	0
			Philopotamidae	Chimarra	sp	0	0	1
			Hydropsychidae	Hydropsyche	sp	2	42	16
		Plecoptera	Pteronarcyridae	Pteromecella	*P. banks*	1	0	0
		Diptera	Empididae	Hemerodrominae	sp	1	0	0
			Sciomyzidae	Tetanocera	sp	1	0	0
			Tipulidae	Hexatoma	sp	0	1	1
			Simullidae	Simulium	sp	1	6	2
			chironomidae	Cryptochironomous	sp	1	1	0
				Bryophaenocladius	sp	1	4	0
				Djalmabatista	*D. pulchra*	0	0	2
				polyperdilum	*P. illinoense*	1	2	4
				Radotanypus	*R. florens*	9	2	4
Total	1	8	35	83	51	275	397	392

III-1-2-3 Numerical structure of benthic macro-invertebrates communities

III-1-2-3-1 Abundance dynamics

A total of 2696 benthic macro invertebrates' individuals were collected in all the 3 streams and its 8 stations throughout the study period in the urban town of Zomba, Malawi. The largest relative abundance of benthic macro fauna was obtain in the Likangala stream with 1259 individuals (47% of the total abundance) this was followed by the Domasi stream with 1064 individuals with 39 % of the total abundance and the least was the Mulunguzi with just 373 individuals which contributed 14% relative abundance as seen on figure 9

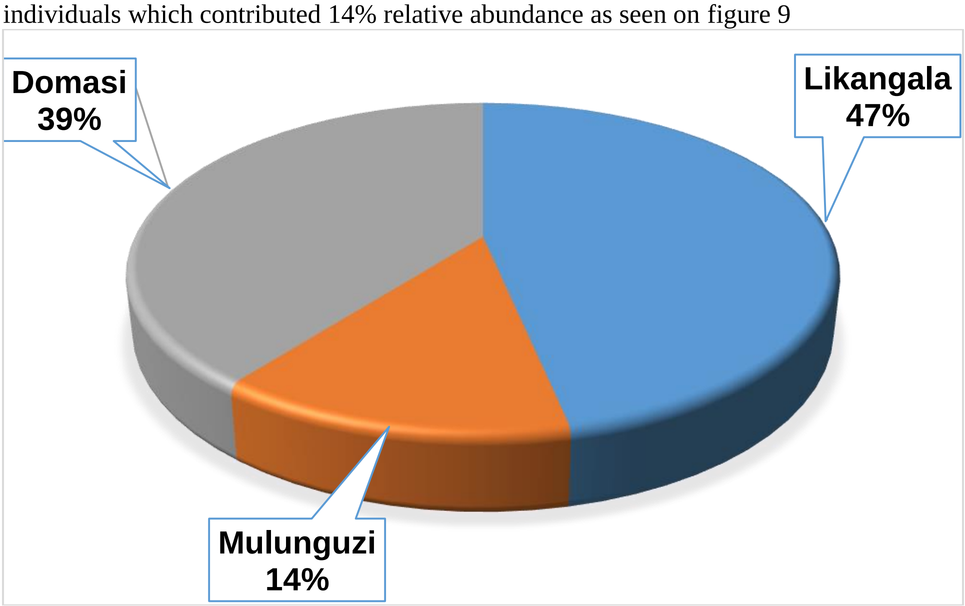

Figure 9: Relative abundance of benthic macro fauna collected streams during the study period

The distribution of this relative abundance in the different sampling sites are shown in figure 10 below. The highest relative abundance (21%) was recorded at the station L3, followed by both L2, D2 and D3 with 15% relative abundance each. L1 and D1 respectively had 11 and 10% relative abundance. The least relative abundance (7%) was recorded in the two stations of the mulunguzi stream (m1 and m2).

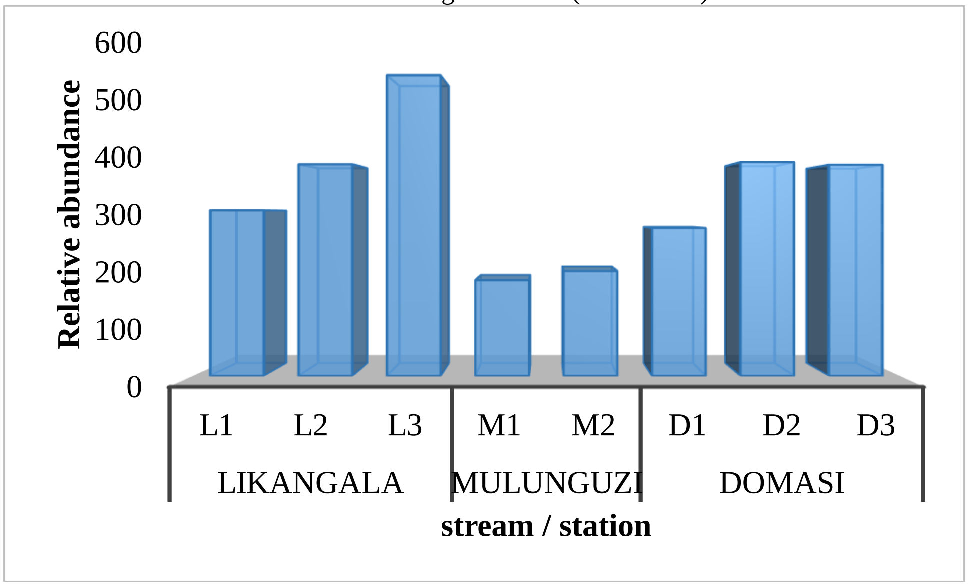

Figure 10: Relative abundance of benthic macro invertebrates recorded in the different sampling sites of the three streams.

III-1-2-3-2 Spatial variation of the different classes of macro fauna relative abundance

The figure 11 below shows the spatial variation of relative abundance in the four classes of benthic macro invertebrates identified in all the stations. We noticed that the class of insects dominated with over 100% relative abundance in almost all the stations except for L1 and L2. At the station L1, insects, malacostraca and Gastropods had 98, 1 and 1% relative abundance respectively. While at L2, insects still dominated with 95% abundance, followed by Achaeta with 4% relative abundance and the least was gastropods with just 1% relative abundance.

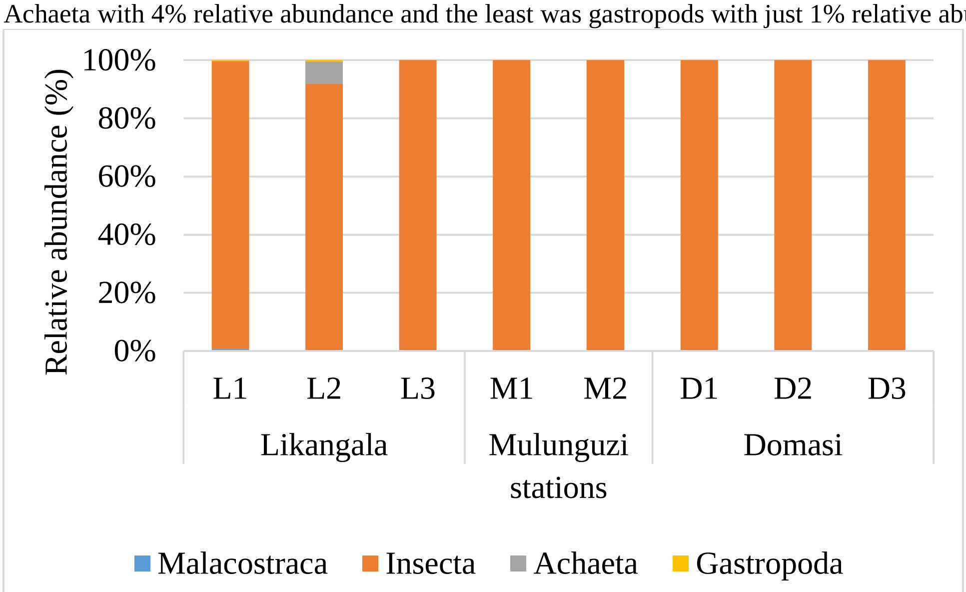

Figure 11: Spatial variation in relative abundance of identified macro-fauna classes

III-1-2-3-3 Spatial variation in relative abundance of benthic macro invertebrate's main orders

The benthic macro invertebrate main orders considered here, are those the represented at least 5% of the total abundance (figure 12)

The station L1, the abundance was dominated by Hemiptera (41%), followed by Odonata (34%). At L2, the abundance was dominated by Odonata (42%), it was next by Diptera (25%) relative abundance. At this same station, we noticed the presence of Rhynchobdellidae with 7% of the abundance while Trichoptera were totally absent here throughout the study period. Moving down to L3, the relative abundance was dominated by Odonata, Ephemeroptera, Hemeptera and Diptera with 38, 33, 17 and 6% respectively. In the Mulunguzi stream, Hemiptera dominated with 50 and 33% it was followed by Odonata with 19 and 25% for M1 and M2 stations respectively. The relative abundance of Diptera increased to 11% at the M2 station. At the D1 station, Ephemiptera (40%) had the highest relative abundance. It was followed by Hemiptera (34%) and the Coleptera with 10%. at D2, it was instead Odonata that had the highest relative abundance of 40% then came Ephemiroptera with 25% and then Hemiptera with 15% relative abundance. Over at D3, the relative abundance went from Hemiptera (31%) to Trichoptera (29%) and the Odonata (21%).

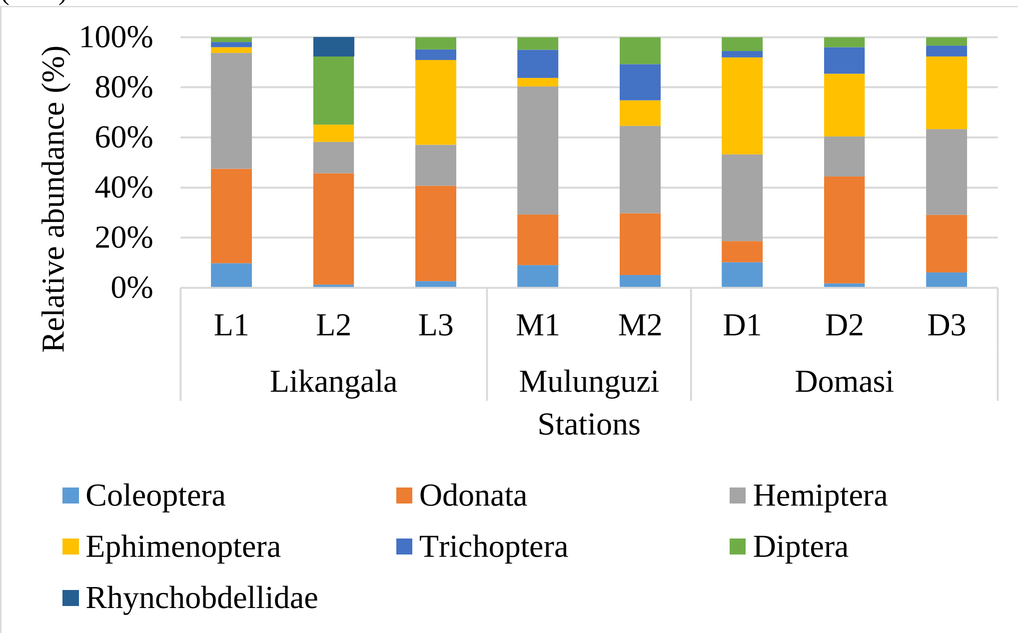

Figure 12: Spatial variation in relative abundance of benthic macro invertebrate's main orders

III-1-2-3-4 Spatial variation in relative abundance of benthic macro invertebrate's main Families

The figure 13 below shows the spatial variation of relative abundance for the macro invertebrate's main families. The families used here are those who represent at least 5% of the total abundance in each station. A total of 11 families all belonging to the class of Insects where chosen. On average, most of families are found in almost all the sampling sites but for families Dytiscidae, Ventidius and Hydropsychidae which are absent at L2. Also, Baetidae was totally absent at the station M1. The L1, L2 and L3 stations were dominated by Calopterygidae with 40, 41 and 38% relative abundance respectively. Still at this stations, the second most abundant were Veliidae (31%) at L1, Chironomidae (32%) at L2 and Baetidae (20%) at L3. In the m1 and m2 stations, it was Veliidae (53 and 21% respectively) that had the highest relative abundance and was followed by Calopterygidae with 11 and 18% relative abundance respectively. Baetidae (40%) had the highest relative abundance D1 while Calopterygidae (34%) and Baetidae (30%) dominated in D1 and D2 respectively. Veliidae came second in all the three stations of Domasi stream.

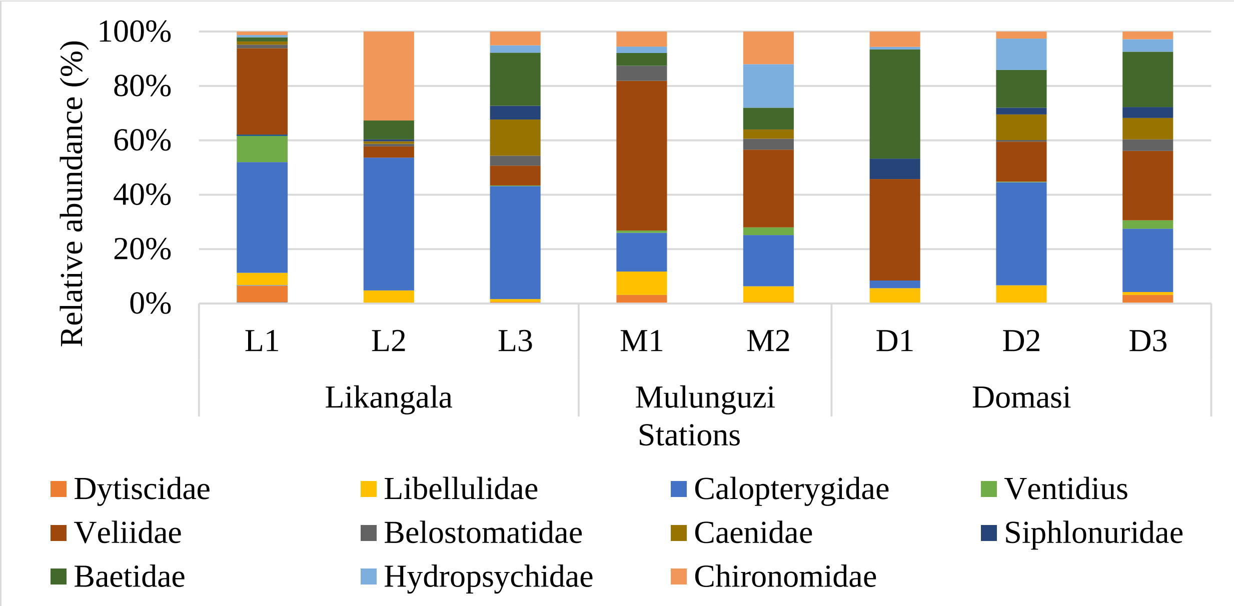

Figure 13: Spatial variation of relative abundance for the macro invertebrate's main families.

III-1-2-4- Density variations of some macro-invertebrates taxa in Malawi

The aim of this section is to understand the spatial variations in density of some taxa which dominated the macro invertebrate community during the research period. The families of Chironomidae and Gerridae were the most abundant and divers during the study period.

III-1-2-4-1 spatial variations of chirinimidae community structure

Comparing the Chironomids collected in Zomba to those of Bamenda, we notice a 50% difference in terms of general and species present. Pollution tolerant taxa Chironomids dorminated in Bamenda while in Zomba, the chironomid community was dives and dominated by pollution sensitive taxa. Members of the chironomidae family were present in all the 8 sampling stations and it also had the highest number of species in the different stations during the study period.

III-1-2-4-1-2 Relative Abundance of chironomidae general

In all, 190 chironomidae individuals were collected as summarized on Table 5. These organisms were identified to belong to 9 general and members of the genera were founf in all the three streams of Zomba. This population was dominated by the genus Chironomus (54%), Radotanypus (18%), Polypedilum (17%), Ablabesmyia (5%), Bryophaenocladius (4%), Cryptochironomus (2%). The genus Djalmabatista and Denopelopia both had 1% while Saetheria represented approximately zero percent (figure 14)

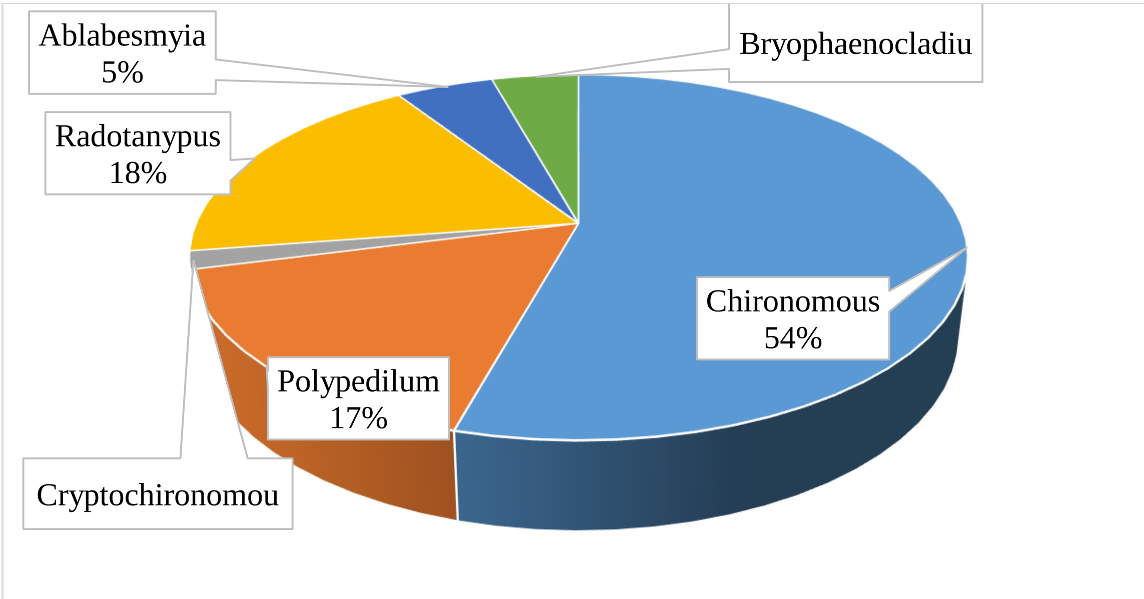

Figure 14: Relative abundance of chironomid general identified

III-1-2-4-1-3 Relative Abundance of chironomidae species per sampling station

Looking at the abundance, we notices that, though the genus chironomus represented 54% with three species (*C. riparus* 23%. *C. stigmaterus* 17% and *C. staegeris* 14%), it was only present in station L2 and a few in L3. It should be noted that this station L2 is situated after the Chikanda default sewage treatment plant and the Zomba center hospital so, all the untreated sewage makes the conditions favourable for this species of Chironomus and reduces the presence of the pollution sensitive species. L3 is the most diversified station with all the species of the Chironimids identified here present. *Radotanypus florens* (18%), *Polypedilum beckae* (9%), *polypedilum illinoeuse* (8%), *Ablabesmyia peleensis* (5%) and Bryophaenocladius sp. (4%) relative abundance, where the most represented in the other stations (figure 15). Other speicies like the *Denopelopia atria*, *Djalmabatista pulchra* and *Saetheria tylus* represented just 1% of the total abundance. It was noted that this species are sinsive to organic pollution reseasn why there were absent at L2. The sub-family Chironominae was the most diversified and was followed by Tanypodinae and Orthocladinae was the least (table 5)

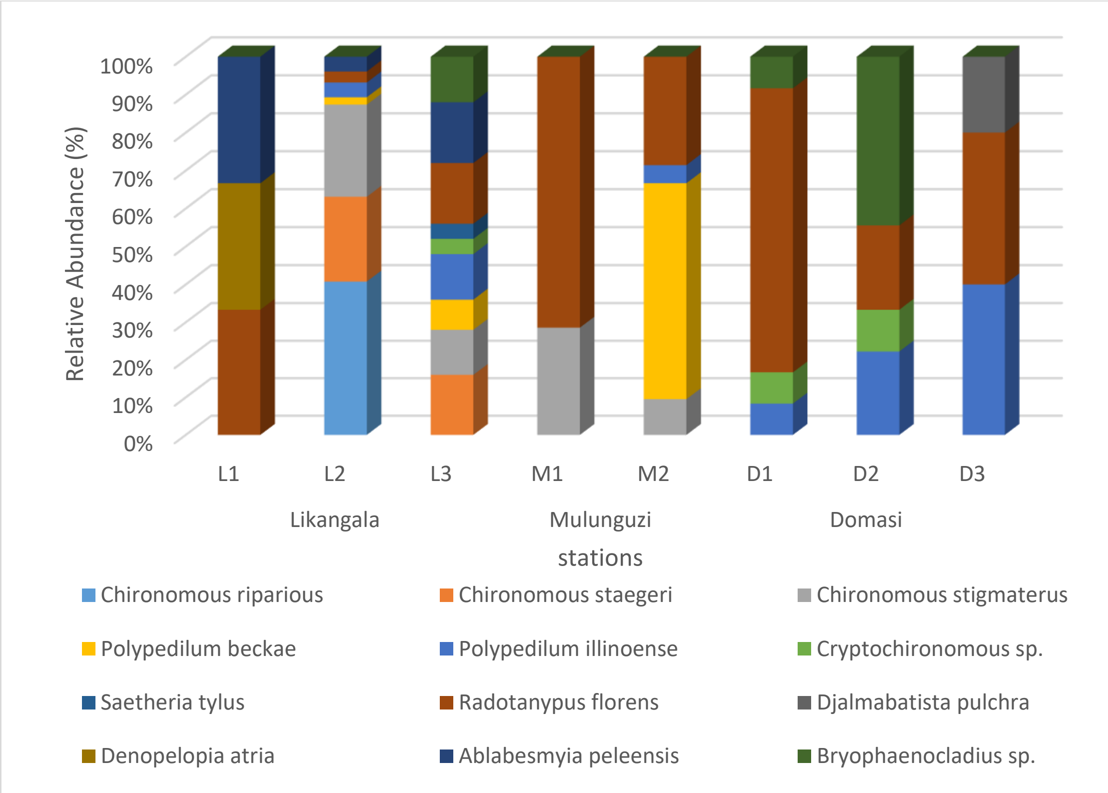

Figure 15: Relative abundance of the different chironomids species in the sampling stations

Table: 5. Summary of the general and species of Chironomidea collected during the study.

Sub family	Genus	Species	Likangala			Mulunguzi		Domasi		
			L1	L2	L3	M1	M2	D1	D2	D3
Chironominea	Chironomous	*Chironomous riparious*	0	42	0	0	0	0	0	0
		Chironomous staegeri	0	23	4	0	0	0	0	0
		Chironomous stigmaterus	0	25	3	2	2	0	0	0
	Polypedilum	*Polypedilum beckae*	0	2	2	0	12	0	0	0
		Polypedilum illinoense	0	4	3	0	1	1	2	4
	Cryptochironomous	*Cryptochironomous sp.*	0	0	1	0	0	1	1	0
	Saetheria	*Saetheria tylus*	0	0	1	0	0	0	0	0
Tanypodinae	Radotanypus	*Radotanypus florens*	1	3	4	5	6	9	2	4
	Djalmabatista	*Djalmabatista pulchra*	0	0	0	0	0	0	0	2
	Denopelopia	*Denopelopia atria*	1	0	0	0	0	0	0	0
	Ablabesmyia	*Ablabesmyia peleensis*	1	4	4	0	0	0	0	0
Orthocladiinae	Bryophaenocladius	*Bryophaenocladius sp.*	0	0	3	0	0	1	4	0
Total	9	12	3	103	25	7	21	12	9	10

III-1-2-4-2-Taxonimic features in mouth parts of identified species in Malawi which were not seen in Bamenda.

In this section, we looked at the morphological characteristics of larvae identified based on their mouth parts structure. Here we focused on the Malawi species that were not descripted in the Bamenda species. The nomenclature is done following the recommendations of Epler (2001).

The *Cryptochironomus sp.* are distinguished by 5 segmented antennae and the mentum has a clear rounded median tooth flanked on it sides by dark and pointed lateral teeth that are angled inward and wide. The mandible is without pecten mandibularis (figure 16A). As for the *Saetheria tylus*, their Mentum is broad with a more arched median tooth. It has 6 or more pairs of lateral teeth. This lateral teeth are straight and pointing forward; ventromental plate with about 15 full length striae (figure 16B). Looking at *Djalmabatista pulchra*, their ligula usually have 5 teeth which are of the same height. The outer teeth are more pointed and dark with a well-developed lateral setal fringe and well developed dorsomental teeth arranged on plates (figure 16C). The Paraligula of *Denopelopia atria* has 2 inner teeth; small claws of posterior parapod with large inner tooth trifid paraligula; lack of well-developed dorsomental tooth plates; 2 small claws of posterior parapod with a large inner tooth; and all claws of posterior parapod pale (figure 16D).

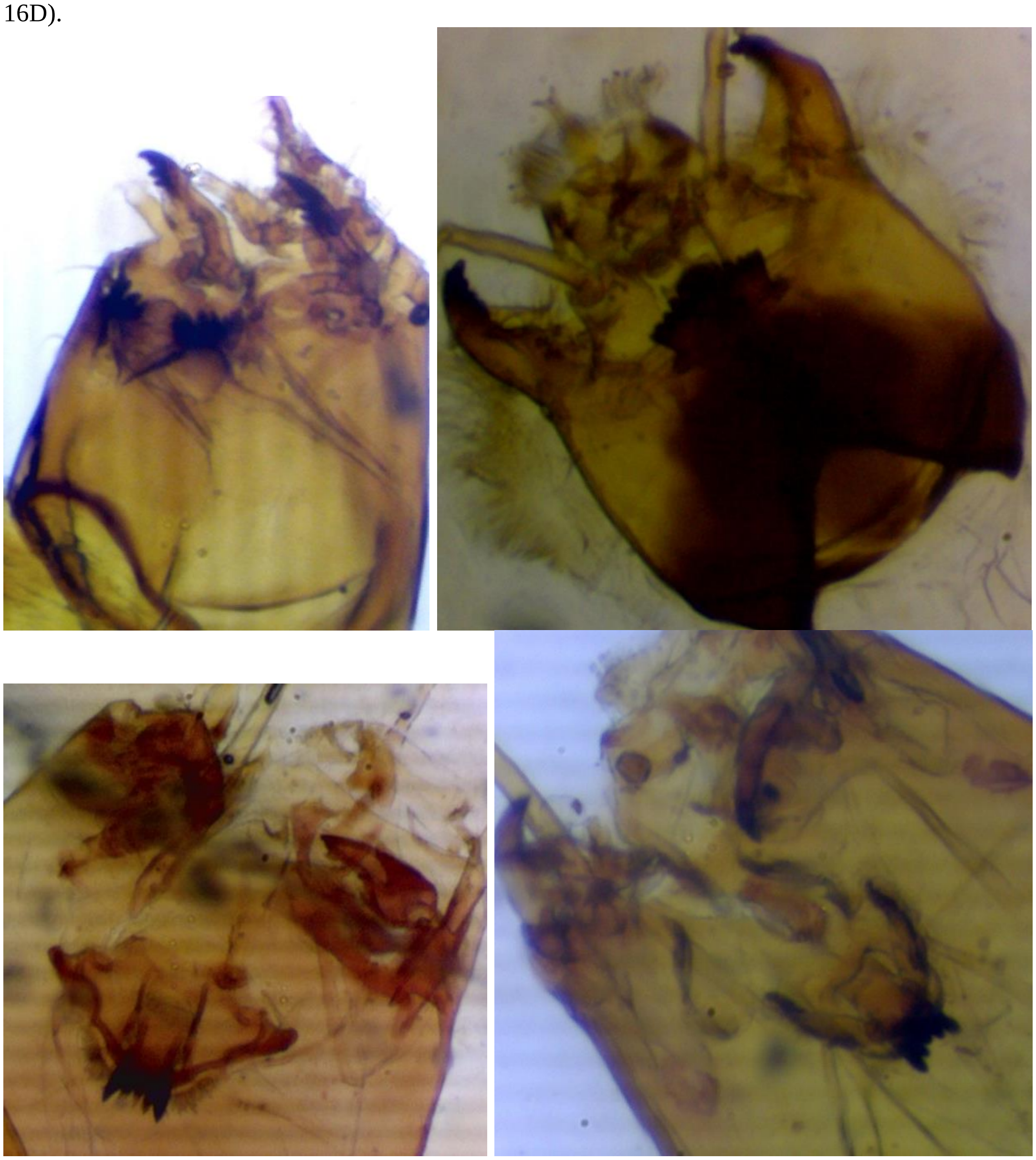

Figure 16: teeth disposition in some chironomids. (A) *Cryptochironomus sp.*, (B) *Saetheria tylus*, (C) *Djalmabatista pulchra*, (D) *Denopelopia atria*.

III-1-2-5 spatial variations of Odonata and community structure in zomba, Malawi

In this study 8 species of dragonflies were identified in to four families and 8 genera. We observed that out of the four families, Calopterygidae recorded 80% of the total abundance, this was followed by Lebellulidae with 11%, Coenogrionidae and Gomphidae both registered 2% of the overall abundance (figure 17). On the number of species, Lebellulidae had the highest (3), followed by Calopterygidae and Gomphidae with 2 species each while Coenogrionidae had just a single species. Station wise, Calopterygidea dominated with over 60% abundance in all the sampling stationd except at D1 where instead Lebellulidae had 57% and calopterygidae had 22 % of the total abundance. The first station of the mulunguzi (m1) was very much diverse and almost all species except few are reported in this area while the second station of Likangala (L2) was very much contaminated and has very few species at that site, but *Caropteryx maculata* was seen most abundant. Station L3 was also contaminated due to the downstream effect but it is less contaminated as compared to station L2. The station D1 was dominated by *Pantala falvesceus* and *Hagenius sp.* which were poorly represented or totally absent in the other stations (figure 18)

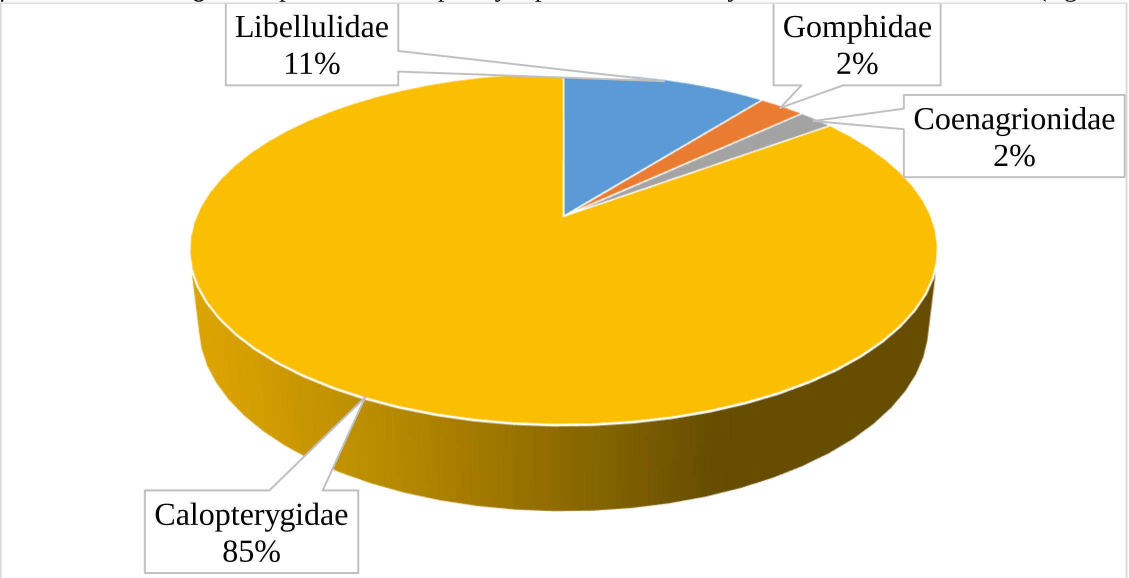

Figure 17: Relative abundance of Odonata families recorded during the study period

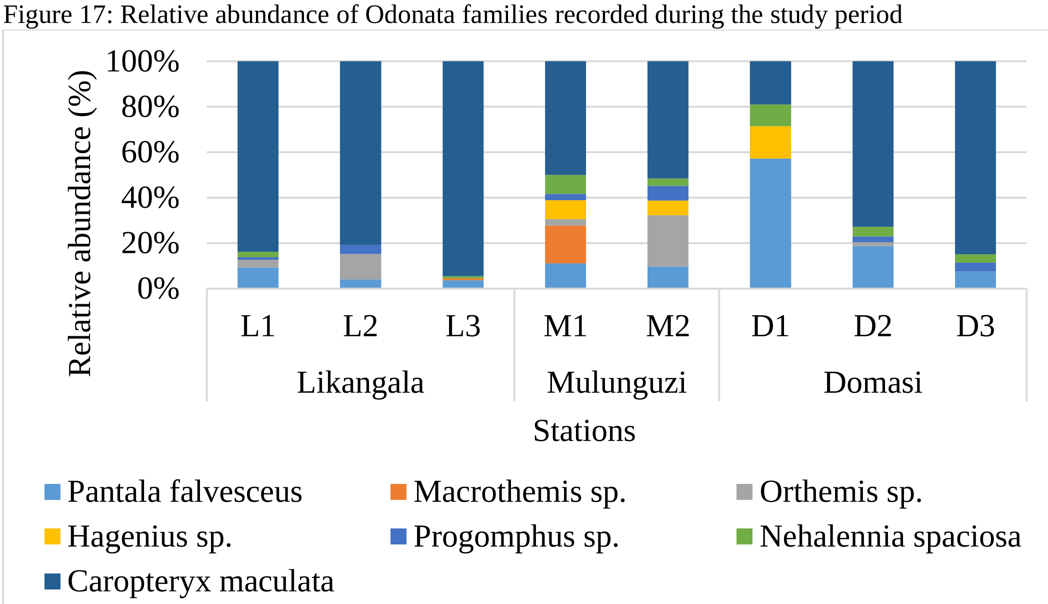

Figure 18: Relative abundance of different Odonata species recorded in the diferent streams

III-1-2-6 Morphological description of *Progomphus sp*. Larvae

III-1-2-6-1 Larval habitat and Distribution

The larvae instars of *Progomphus sp*. were totally absent in all the streams of Bamenda throughout the sampling period. This larva were present in most of the sampling points except for L3 and D1. There were most abundant in L2, D2, M2 and D3. This stations are characterized by a dense network of herbaceous bamboos (*Olyra latifolia)*. At this points, the stream is less rocky compared to the other stations and the base is mostly sandy, turbid and relatively deep waters (4.5 m wide, 3 m deep on average).

Morphologically, this species *Progomphus sp*. looke quite similar to *Progomphus bellei* in few aspect but differ from it at the level of the mentum, eye point, lateral spins and anal appendages.

Colour: the exuviae is brownish yellow with dark sports on it abdomen on it dosal side but light brown on it dorsal side, the head shows many small dark dots (figure 19A). The organim measures 20.4 mm (from the tip of the head to the end of the anal appendages) and 0.8 mm in width (point of largest abdominal segment).

Head. The head of this organism is wider (0.007mm) than long (0.004 mm), it is smaller than thorax (Figure 19A) the cephalic lobes has stiff setae on posterior borders. The antennae bare four-segmented with the third segment being the longest (0.001 mm) while the entire antenna measures (0.002mm) and are covered with setae on the dorsal surface (Figure 19A). The labium is composed of Prementum-postmentum (0.004 mm) is longer and wide (0.003 mm), the sides are straight and slightly divergent apically, the dorsal surface of prementum has no setae except at the anterior part is concaved and lined with stiff setae in its entire length (figure 19B). The Palps are short, thick and ends in hook which are stout, slightly curved and bluntly pointed inwards (figure 19B),

At the level of the thorax, the Pronotum is sub-rectangular, wider (0.006 mm) than long (0.005 mm), with parallel postero-lateral corners slightly rounded. The wing pads are strongly divergent with the anterior wing pads reaching posterior margin of segment 4. The Legs short and thick with its femur (0.005mm), tibia (0.003 mm), tarsus (0.003) with 2 tarsus claws each being 0.001mm.

The abdomen is enlarged, slightly widening to its maximum at segment 5 (0.08 mm) and its 19.1 mm in length. Segment 3-9 has well developed sharp lateral spines. The spins on segment 3 – 5 are all looking same in length but are slightly shorter than those spins on segment 6 – 9 which are relatively longer and looks more pointed (figure 19C). We noted the present of dorsal protuberances from segment 1 to 9 but this structures are looking very small and diminishing in size and can be seen as point projections at the edge of the segments. Segment 5 – 9 looks dark brown and appears darker than the other segments. The last abdominal segment bears 4 anal appendages which are pointed, reddish brown in colour and measures 0.003mm (figure 19C)

Figs. 19: *Progomphus sp.* exuviae details on head and abdominal morphology. (A) Granulose head, (1) Third antennae segment, (2) eye sport, (B) Labium, (3) labial palps and movable hook (4) Prementum, (5) rectangular postmentum, (C) Dorsal abdominal segments, (6) sharp lateral spines, (7) 4 anal appendages.

III-2- Discussion

III-2-1- Physicochemical characterization of the stream studied

The low water temperature values recorded during the study period (Likangala 21- 24^{o}C, mulunguzi 14.9 – 21^{o}C and Domasi 17 – 22^{o}C) could be link to the high tree density along the river banks and to the cold environmental temperatures at this season which is offend referred to as the winter season in Malawi. This results are different from those of Lekani, 2008 in her thesis research on the Mulunguzi River at its tributaries. But the results concur with those of Chidya *et al*, (2011) on the Likangala catchment and to Save *et al* (2012) on the Mudi River, Blantyre.

The very low turbidity values (2 – 45 NTU) during the study period could be explain by the low organic content of water and a low influx of mater into the water bodies. In facts in forest zone with high tree and vegetation canopy, we have a high rate of water infiltration and low soil erosion which is the main source of high turbidity in water. This observations are similar to that of Ajeagah *et al*, (2013) in the sub-urban streams in the forest zone of Yaoundé. The very high (85.97±18.03 - 95.47±3.0) percentage saturation of Dissolved Oxygen in Zomba rivers, attest for the good characteristics of revers located in forest zones which are under little of no anthropogenic influence. Such rivers are characterized by high photosynthetic rate due to foliage, the present of raiders which create natural turbulence conditions and recirculation of water that re-oxygenate the entire water colon.

The low values of BOD_5 obtain during the study period (2.26 – 7.02 mg/L of oxygen) shows the low organic and inorganic matter load of this waters and on the low metabolic activities of decomposing organisms herein. The low BOD was liken to low influx of domestic and municipal waste into this streams. The low water content of nitrates (0.01 – 0.4 mg/L), ammonium ion (0.04 – 9.8 mg/L) and orthophosphates (0.01 – 0.5 mg/L) attest for the low water mineralization rate and the low anthropogenic nature of the streams distinguished by a low influx of allochtonic matter, nor organic matter nor nitrates or phosphate metabolic waste of human activities in an urban town like that of Zomba.

The mean pH values of the three streams Likangala (7.88±0.12), Mulunguzi (7.47±0.47) and Domasi (7.79±0.28) is about the neutral point. This pH could be attributed to substrate pH. According to Lekani (2008), this substrates are sandy/clay with a slight basic pH. The results are consistent with a study conducted by Palamuleni (2002) in South Lunzu streams in Malawi, where pH values were almost neutral. However, our observations contrasts the findings of Sajidu *et al*. (2007) from a study in Blantyre streams, assessing water quality of the streams and waste water treatment where they found a pH ranged of 6.63-9.38 CU.

The very low values of Electrical conductivity (4 – 53 µS/cm) and TDS (2 – 26 mg/L) recorded in the Mulunguzi and Domasi streams show the low mineralization rate of this streams which is link to the fact that the streams receives little urban pollution.

II-2-2 Dynamics of benthic macro invertebrate's taxonomic richness

During the study period, a total of 98 taxa were recorded in all the three streams in the Zomba urban town. This number of taxa are similar to the 96 taxa obtain by Foto Menbohan *et al*. (2013) along the Mfoundi river in Yaoundé but relatively different from the 81 taxa obtain by Tchakonté *et al*. (2015) in the urban towns of Douala. This difference could be explain in terms of pollution levels. The streams of Zomba receives little urban waste while those of Douala receives all the urban waste of the town. The waters were largely dominated by Arthropods (92 taxa) especially by the class of insects (90 taxa) could be link to the high dissolved oxygen level and low turbidity. The second reason for the high taxonomic richness observed in all the three streams could be link to the fact that this streams though in an urban town, receives little or no waste and the streams are relatively stable and heterogeneous to harbor large species number.

The present of Glossiphoniidae, Physidae and the sub family of Chironomus at the second stations of Likangala (L2) which are considered to be pollution tolerant groups and are totally absent in the other 7 sampling stations attest the poor water quality of this station (L2).

II-2-2-1 Chironomid communities and diversity

There were increasing species richness and diversity of chironomids with decreasing levels of pollution and therefore suggest that chironomid species richness and diversities could be used as indicators of water quality changes. The subfamily Chironominae was richer in species and shows a clear distinction between species of the sub-families Tanypodinae and Orthocladinae in sensitivity to pollution. Species of Tanypodinae and Orthocladinae were particularly vulnerable to pollution and were absent at L2. The high abundance of *Chironomus* spp. in the polluted sites L2 and L3 was expected because of their ability to tolerate oxygen depletion and they have been reported in several studies at polluted sites (Allan ,. 2004). The high abundance of the genus *Chironomus* at the polluted sites is probably due to its ability to use haemoglobin for oxygen transportation and individuals within this genus are therefore able to survive in oxygen depleted environment (Adriaenssens *et al.*, 2004).

The numbers of species of subfamily Tanypodinae were highest at the stations m2 and D1 and *Denopelopia atria* and *Ablabesmyia peleensis* occurred just at L1 while *Djalmabatista pulchra* occurred just at D3. Most species of Tanypodinae were reported to be sensitive to water quality changes (Ochieng *et al.*, 2008) which is also reflected in the present study. The higher chironomid species richness and diversity at site M1, D1 and D3 than at sites L2 and L3 equally suggest less impact at this site. The species, *Denopelopia atria, Djalmabatista pulchra*, *Bryophaenocladius sp. Saetheria tylus, Cryptochironomous sp.* and *Ablabesmyia peleensis* appeared to be more sensitive taxa, being less common at the downstream sites. Our observations suggest that the family Chironomidae, identified to species or genus, can be used to assess environmental water quality status in freshwater ecosystems because of their varying degree of sensitivity to changes in environmental water quality. It also revealed that species sensitive taxa were more positively correlated with high DO level while nutrients and EC were the main factors responsible for the observed structure in downstream sites. This observations corroborate that of Ajeagah *et al*. (2013) in the city of Yaoundé, where they noticed increased nutrient and E.C levels in water caused the disappearance of sensitive and less adapted chironomids groups, Akindele E. O. et Adeniyi, I. F. 2013. The relative abundance of *Progomphus* sp. observed in most of the sampling sites except at L3 and D2 could be linked to the soft and fine sandy nature of the stream bed. At the stations (L3 and D2) the waters flow over a rock and are less sandy. Various studies emphasized the importance of river substrate type on the distribution and diversity of Odonata (Assis *et al*., 2004). These characteristics related to the hydrodynamic of environments and distribution of Odonata larvae were also observed in this study. The absent of species like Macrothemis sp., Hagenius sp. and Nehalennia spaciosa from the second station of the Likangala (L2) could be due to the fact that, there are sensitive to organic pollution since the station showed a relatively high nutrient load and mineralization; Angelier 2003.

Conclusion

The present study showed that the distribution and abundance of aquatic insect families and genera are influenced by the physical and chemical condition of the stream. Change in physical nature altered the stream insect community structure. This change in functional groups and habits of stream insects could fundamentally alter the stream ecosystem function. This in turn could directly affect the diversity and distribution of other fauna such as fishes which depend upon stream insects for their survival. By studying the stream channel insect fauna the study has provided valuable insights into aspects of the stream channel ecosystem function.

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