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A Preliminary Study on Abundance and Diversity of Aquatic Macro Invertebrates of Nzovwe Stream, in Mbeya, Tanzania

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Abstract: **The purpose of this current study was to determine the diversity, species richness, dominance and evenness of macroinvertebrates fauna found in Nzovwe stream. The study was carried out from 02 November to 28 December 2015. A total of 584 aquatic macroinvertebrate from 7 orders and 16 species were recoded. They belonged to 22 families. This study shows that Odonata (35.96%) was the most dominant order according to total number of individuals, followed by Hemiptera (25.514%), Coleoptera (19.007 %), Diptera (12.842%), Plecoptera (5.137%), Gastropoda (1.027%) and Ephemeroptera (1.027%). The most abundant species were Dragonflies (27.226%), Water striders (13.185%), and Creeping water bugs (10.274%), whereas the least abundant species were Giant water bugs and Backswimmers (0.514%). The Shannon-Wiener Index diversity and Evenness index (Pielou's index) was higher in order Coleoptera (1.33) and Diptera (0.940) respectively. Ephemeroptera, Plecoptera and Gastropoda (Shannon's, H' = 0.00) were the lowest. Simpson's Reciprocal Index diversity was highest in order Coleoptera (3.400) while Ephemeroptera, Plecoptera and Gastropoda (1/D = 1.000) were the lowest. The species richness of macroinvertebrates was calculated by using Margalef's Index. Moreover, it was found that the stream is poorly managed and threatened by pollution from domestic wastes.**

Keywords**: Macroinvertebrates, Species richness, diversity, abundance, Water quality, Water pollution, Ecosystem, Nzovwe stream.**

1. INTRODUCTION

The aquatic communities in Nzovwe stream are poorly known. On-going stream degradation and pollution threaten the existence of numerous species before they are even described, because its aquatic ecosystems are most affected by human activities. For instance, farming is one of the degrading factors that affect aquatic ecosystems of Nzovwe stream [1]. This study contemplates the community of macroinvertebrates that commonly used as bioindicators of water quality. This is because they have some characteristics that make them easy to study, and show perfect responses when encountered with adverse environmental conditions [2].

Aquatic macroinvertebrates live in different waterways such as rivers, streams, ponds, wetlands but also in lakes [3]. Their occurrence and distribution in different parts of water body, such as from the upstream to downstream and from the surface to the bottom, is frequently governed by the physico-chemical quality of water and immediate substrate of occupation [4]. Temperature, dissolved oxygen, pH and nutrients have considerable effects on the life of aquatic organisms [3, 5]. Similarly, the macroinvertebrate community can vary depending on geographical differences and water bodies. Triest *et al.*, [5] explained that the macroinvertebrates are useful indicators of ecosystem health or condition of wetlands and other water bodies because they can respond to several kinds of pollution, such as chemical pollution or any other physical disturbance to the wetland structure and hydrology. This may be due to their high sensitivity to physico-chemical conditions of the water body, including but not limited to pH, salinity, dissolved solids, suspended solids, turbidity, conductivity, temperature, and dissolved oxygen [6].

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Furthermore, aquatic macroinvertebrates are unique because they play an important ecological role for survival of life on earth [7]. Large diversity of aquatic macroinvertebrate is indeed an intrinsic part of the earth's ecosystem [2, 6]. These macroinvertebrates have been extensively used as bioindicators of water quality in many developed countries such as in Europe, Canada and United States and are included in their national and technical standards of water quality monitoring [8]. In developing countries such as in Tanzania, Kenya, Uganda, Rwanda, their use is still very limited [9, 10]. The diversity which includes both richness and evenness of macro-invertebrate community in the water can be seen as indicators of good ecological water quality, while the decreasing of its community or the excess developing of particular species in the water is an indication of unhealthy or ecological degraded water quality conditions [11]. The life span of macroinvertebrates is longer, for instance, can stay alive up to a year and greater, thus they can indicate long term water quality unlike other organisms such as diatoms [12]. Moreover, the macroinvertebrates are easy to be sampled, collected, preserved, sorted and identified [11]. Apart from being useful indicators of water quality and or ecosystem health of many water bodies such as river, streams and wetlands, they do also play an important role in the aquatic food chains because many larger aquatic animals rely on them as the food sources [13].

Because of pollution in aquatic environment caused by the anthropogenic activities may cause dwindling in abundance, diversity and species richness of aquatic species particularly macroinvertebrates sensitive to pollution [7, 14]. And due to continuing threats to aquatic ecosystem and form of life in Nzovwe stream, thus understanding the abundance, diversity and species richness of macroinvertebrates is important in management of this stream. This study is therefore aimed to assess the abundance, diversity and species richness of aquatic macroinvertebrates fauna of Nzovwe stream.

2. MATERIALS AND METHODS

2.1 Study area:

The study area was Nzovwe stream (8° 53′24″S 33° 25′48″E) (Fig.1). It is found in Mbeya city (08°54′S 33°27′E) in Tanzania [1, 15]. The stream separates Nzovwe and Iyunga wards. The stream receives water from several small tributaries from different areas of Nzovwe and Iyunga wards. It usually overflows during rain seasons. The stream is important because supplies water for domestic use and agricultural activities. It also supplies several ecosystem services to neighbouring households as explained by Ojija [1]. The stream is continuously been polluted due domestic wastes disposal and agricultural activities. All these actions do threaten the health of aquatic environment and other aquatic form of life present in the stream.

The site was chosen for this study because of the less known abundance, diversity and species richness of macroinvertebrates in this stream. In fact there is no any other study or published work which documents the diversity and species richness of the macroinvertebrates found in Nzovwe stream except that of Ojija [16] that discussed the use of macroinvertebrates as bioindicators of water quality of Nzovwe stream. His emphasis was the aquatic ecosystem health of the stream.

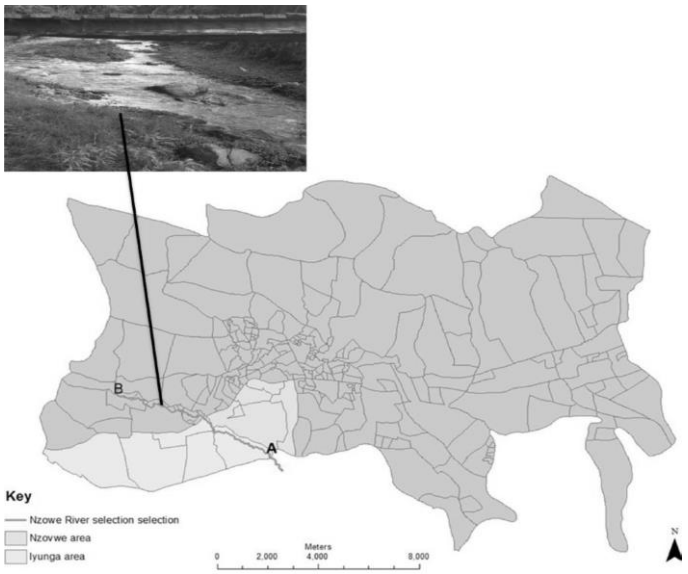

Fig.1 Map showing Nzovwe stream (A-B) in Mbeya town. Source: Ojija [1].

2.2. Methodology:

A total of thirteen samples from thirteen sites were collected from Nzovwe stream. Sampling sites were identified with an objective of obtaining representative aquatic macroinvertebrates samples from the stream. Macroinvertebrates were collected from 02 November to 28 December 2015. At each site aquatic macroinvertebrates were collected using aquatic nets (dip net) and manually using hands. Every single macroinvertebrate in the sample was picked; both the largest and least mobile macroinvertebrates were picked as well; this was to ensure that sampling data are valid. Preservation of specimens was in 70% ethanol. These samples were supplemented at each site by actively finding and collecting numerous adult Odonata by using hands and an aerial net. Identification of macroinvertebrates were done in the biology laboratory at Mbeya University of Science and Technology to the family level using a hand lens, microscope and applicable references and identification key[17, 18, 19].

2.3. Data analysis:

2.3.1. Measurement of Diversity

The diversity of macroinvertebrates used in this study is α- diversity which refers as the diversity of species within a community or habitat. The diversity index was calculated by using the Shannon–Wiener diversity index [20, 21]. The Shannon diversity index (H) is frequently used to characterize species diversity in a community [22-24].

Shannon-Wiener diversity index (H) = $-\Sigma PiInPi$

where Pi = S/N

S = total number of individuals of one species

N = total number of all individuals in the sample

ln = logarithm to base e.

Another index used to calculate the diversity was a Simpson's diversity index [24]. This index is a measure that accounts for both richness and proportion (percent) of each species, and it has been a useful tool to both terrestrial and aquatic ecologists [22, 23, 26, 27].

Simpson's index (D) = ΣPi^2

where Pi = S/N

S = total number of individuals of one species

N = total number of all individuals in the sample

Furthermore, the diversity of macroinvertebrates of Nzovwe stream was also calculated using the Simpson's index of diversity (1–D) as well as the Simpson's Reciprocal Index. The Simpson's Reciprocal Index was calculated using the formula below.

Simpson's Reciprocal Index (1/D) = $1/\Sigma(Pi^2)$

where Pi = S / N

S = number of species

N = total number of individuals

The Simpson's index of diversity was calculated by taking 1–D.

2.3.2. Measurement of species richness:

Species richness of macroinvertebrates was calculated using the Margalef's index [28]. The Margalef's index is given by the formula;-

Margalef's index = (S – 1)/In N

S = total number of species

N = total number of individuals in the sample

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In = natural logarithm

2.3.3. Measurement of evenness or equitability:

The Pielou's Evenness Index [21, 27] was used to calculate the evenness of macroinvertebrate species.

Pielou's Evenness Index (e) = H/InS

H = Shannon – Wiener diversity index

S = total number of species in the sample

2.3.4. Measurement of dominance index:

The dominance index of macroinvertebrate taxa was calculated using the formula below as explained by Belamkar and Jadesh [22].

Relative dominance = (100/N)*ni,

where N stands for the total number of individuals of all species

ni represents the number of individuals of species

3. RESULTS

In this study, a total of 584 aquatic macroinvertebrate were collected from Nzovwe stream as shown in table 1 and 2. Similarly the table 1 shows aquatic macroinvertebrates collected from each sampling site. Sampling site with a large number of macroinvertebrates was site 11 with the total number of macroinvertebrate individuals 64, followed by site 8, 2, 5 and 1 with 60, 56, 52 and 50 macroinvertebrate individuals respectively, whereas site 3 had the least number of macroinvertebrates equal to 27 individuals (Table 1). These macroinvertebrates belonged to 24 families and 7 orders; and about 16 species were recorded from Nzovwe stream (Table 2). It was found that Odonata (35.96%) was the most dominant order according to total number of individuals, followed by Hemiptera (25.514%), Coleoptera (19.007 %), Diptera (12.842%), Plecoptera (5.137%), Gastropoda (1.027%) and Ephemeroptera (1.027%) (Fig.2). The most abundant species were Dragonflies (27.226%), Water striders (13.185%), and Creeping water bugs (10.274%), whereas the least abundant species were Giant water bugs (0.514%) and Backswimmers (0.514%) as presented in Table 1. Furthermore, the Shannon-Wiener Index diversity was higher in order Coleoptera (H'=1.33), whereas Ephemeroptera, Plecoptera and Gastropoda (H' = 0.00) were the lowest (Table 3 and Fig. 3). Evenness index (Pielou's index) was higher in order Diptera (0.940) and lowest in order Ephemeroptera, Plecoptera and Gastropoda. Simpson's Reciprocal Index diversity is highest in order Coleoptera (3.400) and lowest in order Ephemeroptera (1.000), Plecoptera (1.000) and Gastropoda (1.000) (Table 3). Moreover, the species richness of macroinvertebrates calculated by using Margalef's Index was highest in order coleoptera (0.85) and Hemiptera (0.60) (Table 3). Simpson's Index was highest in odder Ephemeroptera, Plecoptera and Gastropoda (1.000).

Table 1: Aquatic macroinvertebrates collected from thirteen sites in Nzovwe stream

	Sampling sites														
Invertebrates	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Total**	**Percent-age**
Dragonfly nymphs	12	16	3	7	6	9	2	5	1	3	9	6	5	84	14.38
Adult dragonflies	7	11	2	13	0	0	8	3	4	11	9	7	0	75	12.84
Water striders/water skaters	9	7	1	4	14	8	3	9	3	5	5	9	0	77	13.18
Lesser water boatman	1	0	1	0	0	0	1	0	1	0	2	0	0	6	1.03
Pouch snails	0	0	0	0	0	0	0	3	0	0	0	1	2	6	1.03
Predaceous diving beetles	1	0	0	3	0	4	0	12	1	5	7	0	9	42	7.19
Creeping water bugs	11	3	6	7	9	5	3	1	1	0	0	3	11	60	10.27
Damselfly nymphs	2	3	4	1	5	6	3	3	4	8	2	7	3	51	8.73

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Stonefly nymphs	0	0	2	0	0	3	7	4	3	3	8	0	0	30	5.14
Crane flies	3	7	1	4	10	8	3	2	4	0	5	0	1	48	8.22
Midges	0	7	3	0	3	1	1	3	0	0	5	1	3	27	4.62
Mayfly larva	1	0	1	0	0	1	0	0	1	0	2	0	0	6	1.03
Riffle beetles	0	1	2	0	0	0	0	2	0	0	0	1	0	6	1.03
Water scavenger beetles	0	0	1	5	0	0	0	5	8	11	3	0	0	33	5.65
Giant water bugs	0	0	0	0	0	0	0	0	0	1	0	0	2	3	0.51
Crawling water beetles	3	0	0	0	5	0	2	8	1	0	7	0	1	27	4.62
Backswimmers	0	1	0	0	0	1	0	0	0	0	0	1	0	3	0.51
Total	50	56	27	44	52	46	33	60	32	47	64	36	37	584	100.00
Percentage	8.56	9.59	4.62	7.53	8.90	7.88	5.65	10.27	5.48	8.05	10.96	6.16	6.34	100.00	

Table 2: List of aquatic macroinvertebrates collected from Nzovwe stream

Order/Family	S/No	Macroinvertebrates	Total number of individuals
Coleoptera	1	Riffle beetles	6
	2	Predaceous diving beetles	42
	3	Crawling water beetles	27
	4	Water scavenger beetles	33
	5	Backswimmers	3
		Total	111
Diptera	6	Crane fly	48
	7	Midges	27
		Total	75
Odonata	8	Dragonfly	159
	9	Damselfly	51
		Total	210
Hemiptera	10	Giant water bugs	3
	11	Water striders	77
	12	Creeping water bugs	60
	13	Water boatman	6
		Total	146
Ephemeroptera	14	Mayfly larva	6
		Total	6
Plecoptera	15	Stonefly nymphs	30
		Total	30
Physidae	16	Pouch snails	6
		Total	6
Total number of collected macroinvertebrates			584

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Table 3: Diversity indices for insect orders/Family collected from Nzovwe stream, in Mbeya town, Tanzania

Order/family	Total number of species	Total number of individuals	Shannon-Wiener index	Pielou's index (Evenness)	Margalef index	Simpson's index	Simpson's reciprocal index	Simpson's index of diversity
Coleoptera	5	111	1.33	0.82	0.85	0.29	3.40	0.71
Diptera	2	75	0.65	0.94	0.23	0.54	1.85	0.46
Odonata	2	210	0.55	0.80	0.19	0.63	1.58	0.37
Hemiptera	4	146	0.91	0.66	0.60	0.45	2.23	0.55
Ephemeroptera	1	6	0.00	0.00	0.00	1.00	1.00	0.00
Plecoptera	1	30	0.00	0.00	0.00	1.00	1.00	0.00
Gastropoda	1	6	0.00	0.00	0.00	1.00	1.00	0.00
Total	16	584						

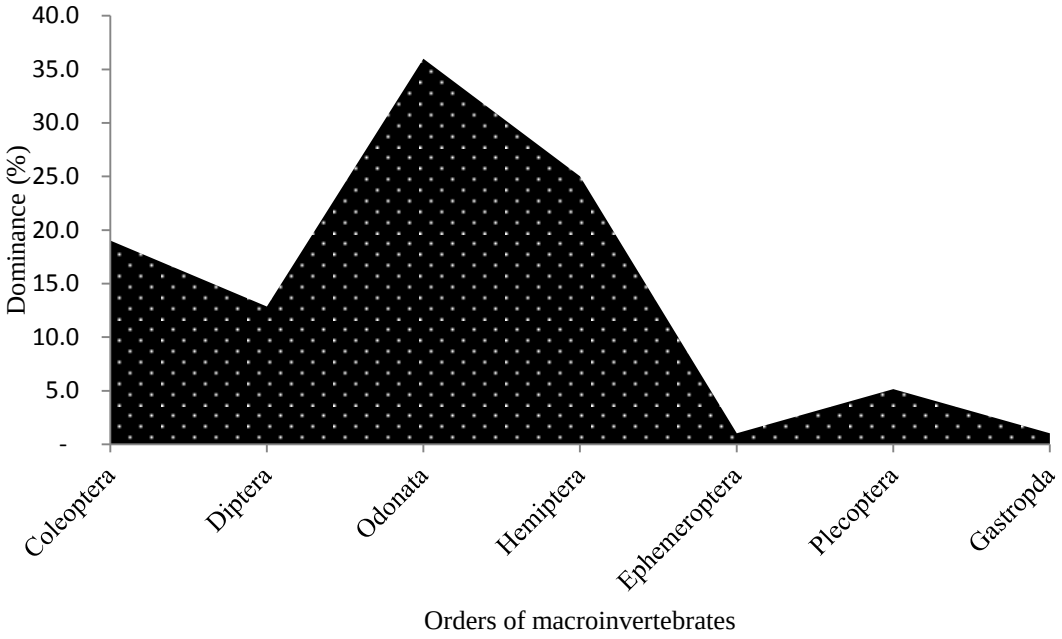

Fig.2. Dominance of aquatic macroinvertebrates in different orders

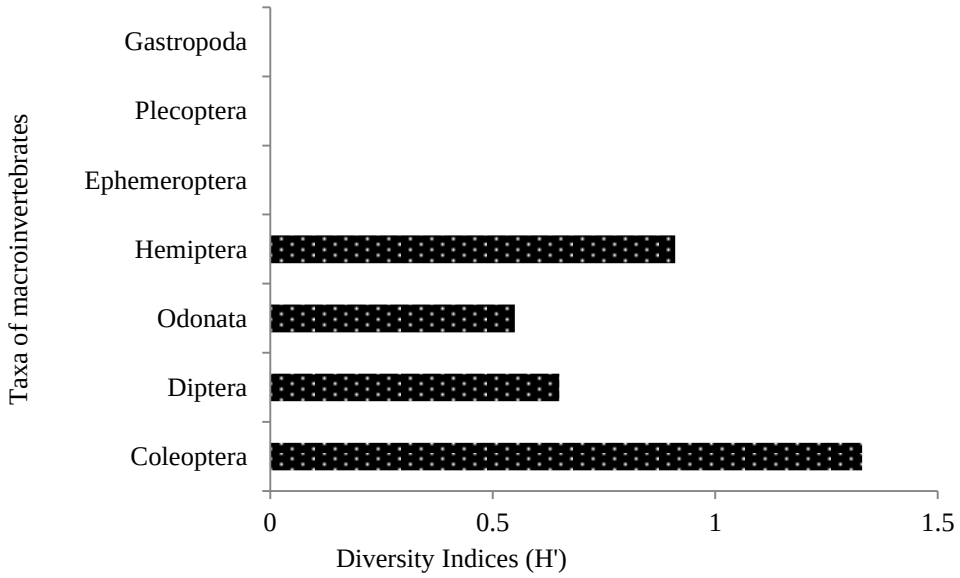

Fig.3. Diversity Indices (H'= Shannon Weiner diversity Index) of macroinvertebrates in Nzovwe stream

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Fig.3 (a) example of macroinvertebrate taxa and (b) sampling and collection of aquatic macroinvertebrates from (c) Nzovwe stream

4. DISCUSSION

Abdelsalam and Tanida [29] show that benthic macroinvertebrate assemblages are structured according to physico-chemical parameters that define habitats, and other biological parameters that influence their reproductive success and hence their abundance as well diversity. The Nzovwe stream is dominated by group of macroinvertebrates which are moderately pollution-sensitive and pollution tolerant organisms, such as Crane fly, Dragonfly, Damselfly, Predaceous diving beetles, Crawling water beetles and Water scavenger beetles [30, 31] (Table 2). Characteristically these organisms can survive in fair water quality because their habitat requirements are not as strict as pollution-sensitive organisms, such as mayflies, stoneflies and caddisflies [31-34].

This study shows that the Nzovwe stream has high diversity and abundance of aquatic macroinvertebrates fauna which comprise 584 organisms belonging to 22 families and 7 orders. The majority of macroinvertebrates found in this poorly managed stream were Odonata (35.96%), Hemiptera (25.514%), coleoptera (19.0075%) and Diptera (12.842%) as showed in Fig.2. Their dominance may be attributed by the water quality [35] or ecosystem health of Nzovwe stream. Many Ordanata and Coleopterans prefer less polluted aquatic environment while Hemiptera are very tolerant to pollutants, however they can also be found in moderately polluted water [35, 36]. Furthermore, the high diversity of Hemiptera (H = 091), Diptera (H = 0.65) and Odonata (H = 0.55) can be promoted by their ability to survive in moderately polluted aquatic environment. This is similar to what explained by Mophin-Kani and Murugesan [37].

Coleopterans collectively known as beetles constitute the largest order of all animals [22]. In this present study it has been analysed that order Coleoptera recorded highest Shannon-Wiener index of diversity (H = 1.33), highest species richness (Margalef's Index = 0.85), highest Simpson's reciprocal index diversity (1/D = 3.40), highest Simpson's index of diversity (1-D = 0.71) and highest Pielou's index (evenness = 0.82) following that of Diptera (evenness = 0.94) (Table 3). In addition of being able to live in moderately polluted aquatic environment, their high abundance, diversity and species richness than other orders in the stream may be supported by to their ability to breakdown plant and animal debris as well as their predatory activities [38-40].

Moreover, it was observed that the abundance, species richness and diversity of Ephemeroptera and Plecoptera were the lowest. For instance, the Shannon-Wiener index of diversity (H = 0.00), species richness (Margalef's Index = 0.00), Simpson's reciprocal index diversity (1/D = 1.00), Simpson's index of diversity (1-D = 0.00) and Pielou's index (evenness = 0.00) (Table 3). Their abundance was 5.137% (Plecoptera) and 1.027% (Ephemeroptera) (Fig.2). The low abundance, species richness and diversity of the two orders may be due to presence of pollution that has altered the physico-chemical properties and hence water quality of Nzovwe stream. This is because the two orders comprise organisms which are very sensitive to pollution and thus they cannot produce, colonize and survive successful in poor water quality environment [37, 41].

Sources of pollutants in the stream could be due to the farming activities nearby the stream which causes soil erosion and consequently increasing suspended particles into the stream. It was further observed that farming activities that employ the use of synthetic fertilizers, pesticides, and weedicides, and settlements which demands space are other factors contributing to pollution of the aquatic environment of Nzovwe stream [1]. Furthermore, Kripa *et al*., [42] argued that human intervention in the name of development has largely affected many natural aquatic ecosystems over the world. This is not very far from what is affecting and facing the ecosystem of Nzovwe stream as well its form of life.

5. CONCLUSION AND RECOMMENDATION

This piece of work was an attempt to describe some aspects of biodiversity of macroinvertebrates of Nzovwe stream. From this study, the Nzovwe stream is still considered to have a diverse and several aquatic macroinvertebrates. Yet, the results which are presented in this paper might be the first least list of macroinvertebrates in the stream. Therefore, further researches are necessary in order to obtain an estimate and unbiased information on diversity, species richness, evenness and dominance of numerous macroinvertebrates taxa from Nzovwe stream. Generally the study revealed that the Nzovwe stream support a good abundance and diversity of aquatic macroinvertebrates.

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