Macro Invertebrates As Bio Indicators Of Water Quality In Nzovwe Stream, In Mbeya, Tanzania

Fredrick Ojija, Hudson Laizer

Abstract: This study was carried out to assess the water quality of Nzovwe stream using macroinvertebrates as bioindicators. Biological monitoring working party (BMWP) scoring system was the index used to assess the ecosystem health of Nzovwe stream. A total of 584 aquatic macroinvertebrates were identified from Nzovwe stream. They belonged to 22 families. The most abundant taxa were Odonata (35.959%), Hemiptera (25.514%), Coleoptera (18.493%), and Diptera (12.842%). Whereas the least abundant taxa were Ephemeroptera and Gastropoda, each constituting 1.028% of all macroinvertebrates. The most abundant macroinvertebrates were Dragonflies (27.226%), Water striders (13.185%), and Creeping water bugs (10.274%), whereas the least abundant were Giant water bugs (0.514%) and Backswimmers (0.514%). The BMWP score of Nzovwe stream was 115. Based on this score, the water of Nzovwe stream is neither very clean nor significantly altered aquatic environment. Hence the Nzovwe stream is moderately polluted due to non-point source pollution from several sources. Moreover, it was found that agricultural activities, washing and bathing could alter physico-chemical parameters of the stream and hence changing the abundance of macroinvertebrates as well as the quality of water. This study, therefore, recommends that the source of pollutants should be controlled and the stream regularly monitored by the relevant authorities. Additionally, biological indicators and their indices are suggested to be used in assessing the condition of a stream ecosystem.

Key words: BMWP scoring system, Bioindicators, Macroinvertebrates, Water quality, Water pollution, Ecosystem services, Nzovwe stream

1. Introduction

Pollution of aquatic environment caused by the anthropogenic activities, degradation and misuse of natural resources has been increasing in our planet [1, 2, 3]. This has been witnessed in the last few decades [3]. Due to this, several countries have established policies that protect environment from anthropogenic threats and to provide a proper way of using water resources [4, 5]. On the other hand it is important to understand that the availability of clean freshwater is essential for all form of life in our planet. Henceforth, understanding the ecology of freshwater is vital not only because of its biological implications, but also because the proper management and conservation of freshwater is necessary to any living organism including human being. In Tanzania, most cities contain a number of fresh water bodies such as lakes and rivers together with a small network of streams. Most of these freshwater ecosystems have been subjected to an increasing pollution load from contaminated urban run-off water coming from industrial, agricultural, residential, commercial and recreational areas and institutions such as schools and hospitals [6, 7]. Though there are many sources of natural pressures encountered by aquatic and terrestrial organisms in their habitats, human activities do generate other more environmental pressures [8]. Environmental pressure or stress generated by human can cause harmful alteration, and destruction of freshwater environments [7]. Concerns regarding the management of freshwater bodies led to laws and acts that emphasize the proper management and use of water resources in Tanzania [7, 8].

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Therefore, in order to understand the status of water quality and reduce pollution rate in our waterways (stream and rivers), the knowledge about the health status of aquatic environment including their biodiversity is important [9]. This can be done using various established bioindicators of water quality. Kripa et al., [10] define bioindicators as “a species or group of species that readily reflects the abiotic or biotic state of an environment, represents the impact of environmental change on a habitat, community or ecosystem, or is indicative of the diversity of a subset of taxa, or the whole diversity, within an area’’. Among these bioindicators, the most frequently used are the benthic macroinvertebrates [6, 11, 12]. Macroinvertebrates have been extensively used as bioindicators 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 [11]. In developing countries such as Tanzania, their use is still very limited [6, 11, 13]. Furthermore, Tanzanian environmental laws, acts, regulatory processes and bodies do not emphasize the use of aquatic macroinvertebrates as bioindicators of water quality to evaluate the quality of aquatic ecosystems [6]. This may be due to lack of a well-known and established bio-monitoring system and biotic index within the country [11]. However, currently, very few studies have started using Tanzania River Scoring System (TARISS). TARISS is a macroinvertebrates-based biotic index for rapid bio-assessment of rivers which has been developed recently in 2012 for the evaluation of aquatic environments, based on the South African Scoring System (SASS) [6, 11, 12]. Assessment of water quality in Tanzania is mainly done by analysing physico-chemical parameters and using fecal coliform test as delineated in the national environmental standards compendium by Tanzania Bureau of Standards (TBS) [14]. Due to continuing threats to aquatic ecosystem and form of life in the Nzovwe stream, a better understanding of Nzovwe macroinvertebrates diversity can lead to specific management of this stream. Ojija [15] claimed that the Nzovwe stream is under extreme anthropogenic pressure because of domestic activities and waste disposal in or nearby the stream ecosystem. Also, he showed that there is no on-going monitoring of environmental health and macroinvertebrates in Nzovwe stream; as a result, environmental changes are continuously happening. Although the environmental changes are perceived when streams are highly altered, no serious actions are taken to monitor or to stop these alterations. The ecosystem of Nzovwe stream therefore needs a quick assessment that involves simple approach of sampling, identification and analysis of aquatic macroinvertebrates. And this study on bioindicators of water quality of Nzovwe stream forms the baseline for futures studies. Though there are several macroinvertebrates indices that have been developed to evaluate aquatic environments [2-4, 11-13, 16] this current study uses the Biological Monitoring Working Party (BMWP) to evaluate the environmental health of Nzovwe stream. The Working Party (BMWP) index was developed in 1976 and recommended for use in river pollution surveys [3, 11]. According to Uherek and Gouveia [3], the BWMP is not only simple and easier to apply but also reduces the costs when compared to physico-chemical analyses, which may require sample processing in laboratories; also it requires limited effort to produce precise and repeatable results of environmental monitoring. Although many freshwater bodies are monitored by physico-chemical parameters, Sharma et al., [16] and Maret [17] emphasise that the macroinvertebrates are the most common faunal assemblages for bioassessment because they provide more reliable assessment of long term ecological alterations in the quality of aquatic ecosystem compared to its rapidly changing physico-chemical characteristics. Thus, physico-chemical water tests are inadequate because they only tell us what is in the water at the precise moment the sample is collected. Also, they provide no or less clue of what was in the water an hour ago, yesterday, past days, weeks or months [18, 19]. Nonetheless, at all time, aquatic macroinvertebrates are surrounded by water and any pollutants that may be in the water [19, 20]. If pollutants were in the water an hour ago, yesterday, past days, weeks or months, the total number and diversity of macroinvertebrates present would mirror this in the water quality. This is due to the facts that different taxa of aquatic macroinvertebrates have different requirements to live [20-23]. Some need cooler temperatures, moderately high dissolved oxygen levels or certain habitats, while others can survive where there are low dissolved oxygen levels or more sediment and or where the water temperature is warmer [2, 20]. Accordingly, the freshwater invertebrates can reflect both short and long term shifts in water quality [22, 23]. Freshwater invertebrates can be divided into three groups or classes [24, 25]; (i) pollution-sensitive organisms: These are organisms that require good water quality to survive. They may require clear or non-turbid waters and or high dissolved oxygen levels. For instance, stonefly, water penny, mayfly, and caddisfly [9]; (ii) moderately pollution-sensitive organisms: These are organisms that can survive in fair water quality [25]. Their habitat requirements are not as strict as pollution-sensitive organisms. These include but limited to crane fly, crayfish, dragonfly, damselfly, sow bugs, clams, scuds [22, 24]; and (iii) pollution-tolerant organisms: These are organisms that can survive in poor water quality. Their adaptations allow them to survive in turbid waters, nutrient-enriched waters or in water with low dissolved oxygen. For example, leeches, pouch nails, aquatic worms, midges, water striders, backswimmers, water bugs, and true bugs [26]. Therefore it is recommended to use macroinvertebrates parameters as water quality indicator since they integrate information over longer periods of time and signify the responses of aquatic habitats, making biotic monitoring indices good tools for the sustainable management of water resources [27]. There is no information on the macroinvertebrates species and taxa found in Nzovwe stream, also no assessment of water quality using macroinvertebrates has been done, the purpose of present study was to assess the ecosystem health of Nzovwe stream using aquatic macroinvertebrates as bioindicators.

2. Materials and Methods

2.1 The description of the study area.

The study area was Nzovwe stream (8° 53′24″S 33° 25′48″E) found in Mbeya city (08°54′S 33°27′E) in Tanzania [28] (Fig.1). The stream separates the two wards, Nzovwe and Iyunga. The area experiences adequate rainfall from December to April which ranges from 1400mm-1600mm per year, the remaining months receives no rainfall [29]. The stream receives water from 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 [15]. The stream is continuously been polluted due domestic wastes disposal and farming activities. These activities threaten the health of aquatic environment including all aquatic form of life, animals, plants and local residents. The Nzovwe stream was selected for this study because no any study which has been done to assess the stream water quality using macroinvertebrates as bioindicators.

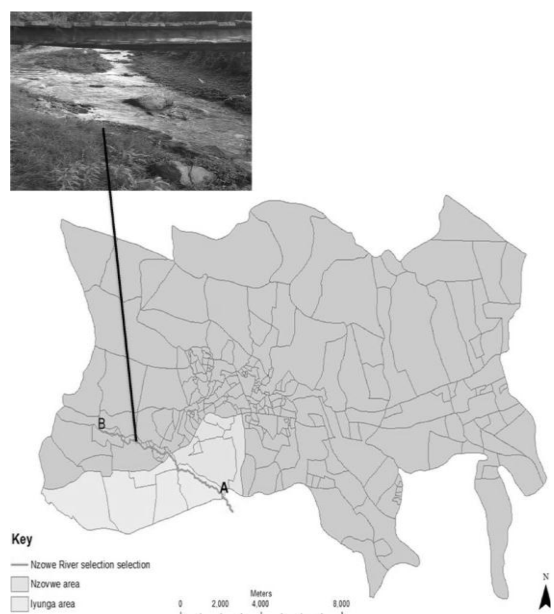

Fig.1 *Map showing Nzovwe stream (A-B) in Mbeya town. Source: Ojija [15]*

2.2. Research methodology

Macroinvertebartes were collected from thirteen sites from Nzovwe stream using semi-quantitative sampling techniques. Sampling sites were identified with an objective of obtaining representative aquatic macroinvertebrates samples from the stream. Macroinvertebrates were collected from 2 November 2015 to 28 February 2016 twice per week. At each site aquatic macroinvertebrates were collected using aquatic nets (dip net) and manually using hands. In order for sampling data to be valid, every single macroinvertebrate, both the largest and least mobile in the sample were picked. Samples were preserved in 70% ethanol. These samples were supplemented at each site by collecting actively several adult Odonata by using hands and an aerial net. Macroinvertebrates were identified in the biology laboratory at Mbeya University of Science and Technology (Fig.2) to the family level using a hand lens, microscope and relevant references and identification key [30-32]. Despite the presence of different biological indices which are used to assess the health of aquatic ecosystems, the index used in this study to assess the ecosystem health of Nzovwe stream is known as Biological Monitoring Working Party (BMWP) scoring system as mentioned earlier. The BMWP scoring system used in this work is that created by Hellawell (Table 2) (as cited in Uherek and Gouveia [3]) and that used by Mason and WMO (Table 3) (as cited in Suleiman and Abdullahi [33]).

(a)

(b)

Fig. 2 *shows (a) sampling and collection of macroinvertebrates and (b) examples of aquatic macroinvertebrates collected from Nzovwe stream*

2.3. Data analysis

According to Uherek and Gouveia [3], Oliveira and Callisto [4], Suleiman and Abdullahi [33], and Sandin and Hering [34] the BMWP requires taxonomic identification of the invertebrates only to the family level nevertheless can take order or class for certain groups. The analytical procedures were identification of macroinvertebrates from each site to family level and assign them with the scores following BMWP scoring system (Table 2 and 3). The overall BMWP score was the sum of all scores of each taxon (family) present in a study site as shown in table 6. In their work, both Alba-Tercedor and Armitage et al., claimed that the total score for a site indicates water quality categories ranging from “good” to “very critical” (as cited in Uherek and Gouveia [3]) (Table 1). And each taxon receives a score that reflects its exposure to pollution; that is, pollution-sensitive taxa receive high scores, while pollution-tolerant taxa are given low scores [33].

3. Results

Table 1 presents BMWP classes, scores, categories and interpretation of the result that used to classify the water quality of Nzovwe stream based on BMWP score system. Table 2 and 3 present the BMWP score table, each family is given a score between 1 and 10 according to the presence or absence of indicator groups and or indicator species in the sample. In this study, a total of 584 aquatic macroinvertebrate were collected and identified from Nzovwe stream as indicated in table 4. They belonged to 24 families (Table 5). The most abundant taxa were Odonata (35.959%), Hemiptera (25.514%), Coleoptera (18.493%), and Diptera (12.842%) representing about 92.808% of the total macroinvertebrates. Whereas the least abundant taxa were Ephemeroptera and Gastropoda, each having 1.028% of all macroinvertebrates (Fig. 3). Macroinvertebrates sampled from thirteen sites are presented in table 4. The most abundant were dragonflies (27.226%), water striders (13.185%), and creeping water bugs (10.274%), whereas the least abundant were giant water bugs (0.514%) and backswimmers (0.514%). Respectively, sampling site with a large number of macroinvertebrates was site 1, 2, 5 with 50, 56, and 52 macroinvertebrates. Site 8 and 11 had 60 and 64 macroinvertebrates individuals respectively, whereas site 3 had the least number of macroinvertebrates equal to 27 individuals. Site 7 and 11 are the only sites with a large number of aquatic organisms which are very sensitive to pollution (>5 stonefly nymphs) as indicated table 4, but the remaining sites had < 5 or none stonefly nymphs or adults. Moreover, table 5 presents class, order and families of macroinvertebrates collected from Nzovwe stream, whereas table 6 present biological scores allocated to each family of aquatic macroinvertebrates. These scores present the presence of indicator groups and or indicator species in the sample. It was found that the calculated total BMWP score of Nzovwe stream is 115 (Table 6). Based on this score, the Nzovwe stream is in class I (101-150), category of ‘good’ with the interpretation of ‘clean or not significantly altered’ aquatic environment (Table 1). Furthermore, it was also found that, somewhat pollution tolerant macroinvertebrates group (Crane fly, Dragonfly, Damselfly, Predaceous diving beetles, Crawling water beetles, Water scavenger beetles) was more abundant (61.64%) in the stream than those which are sensitive to pollution (Mayfly larva, Stonefly nymphs, Riffle beetles) (7.19%) and tolerant to pollution (Pouch snails, Midges, Giant water bugs, Backswimmers, Water striders Creeping water bugs, Water boatman) (31.16%) as presented in table 7.

Table 1: *BMWP classes, scores, categories and interpretation of the result.*

Class	BWMP score	Category	Interpretation
I	>150	Good	Very clean water
	101–150		Clean or not significantly altered
II	61–100	Acceptable	Clean but slightly impacted
III	36–60	Questionable	Moderately impacted
IV	15–35	Critical	Polluted or impacted
V	<15	Very critical	Heavily polluted

Source: *Uherek and Gouveia [3]*

***Table 2**: The Biological Monitoring Working Party Score (BMWP) taxa scores: class, order, or family.*

Taxa	Score
Ephemeroptera: Leptophlebiidae, Leptohyphidae Plecoptera: Perlidae Trichoptera: Brachycentridae, Leptoceridae, Odontoceridae, and Sericostomatidae	10
Odonata: Coenagrionidae, Calopterygidae, Cordulegastridae, Gomphidae, and Libellulidae Trichoptera: Calamoceratidae, Glossosomatidade, Philopotamidae, and Psychomyiidae	8
Plecoptera: Nemouridae Trichoptera: Polycentropodidae	7
Crustacea Trichoptera: Hydrobiosidae, Hydroptilidae	6
Coleoptera: Elmidae, Dryopidae Diptera: Simuliidae, Tipulidae Ephemeroptera: Euthyplociidae, Polymitarcidae Platyhelminthes Trichoptera: Helicopsychidae, Hydropsychidae	5
Arachnida: Hydracarina Coleoptera: Chrysomelidae, Curculionidae, and Haliplidae Diptera: Anthomyiidae, Ceratopogonidae, Chaoboridae, Dixidae, Dolichopodidae, Empididae, Limoniidae, Psychodidae, Stratiomyidae, and Tabanidae Ephemeroptera: Baetidae, Caenidae Megaloptera: Corydalidae, Sialidae	4
Annelida: Hirudinea Coleoptera: Dytiscidae, Gyrinidae, Helodidae, Hydrophilidae, and Noteridae Hemiptera: Belostomatidae, Corixidae, Gerridae, Hydrometridae, Mesoveliidae, Naucoridae, Nepidae, Notonectidae, Pleidae, and Veliidae Mollusca	3
Diptera: Chironomidae, Culicidae, Ephydridae, Muscidae, and Thaumaleidae	2
Annelida: Oligochaeta Blattaria: Blattidae Diptera: Sciomyzidae, Syrphidae, and Rhagionidae Lepidoptera	1

***Source:** Uherek and Gouveia [3]*

***Table 3**: The Biological Monitoring Working Party Score (BMWP)*

Common Name	Families	Scores
Mayflies	Siphlonuridae, Heptageniidae, Leptophlebiidae Ephemerellidae, Potamanthidae, Ephemeridae	
Stoneflies	Taenioptrygidae, Leuctridae, Capniidae, Perlodidae, Perlidae, Chloroperlidae	10
River Bug	Aphelocheidae,	
Caddisflies	Phryganeidae, Molannidae, Beraidae, Odontoceridae, Leptoceridae, Goeridae, Sericostomatidae	
Crayfish	Astacidae	
Dragonflies	Lestidae, Agriidae, Gomphidae, Cordulegasteridae, Aeshnidae, Corduliidae, Libellulidae	8
Caddisflies	Psychomyidae, Philoptamiidae	
Mayflies	Caenidae	
Stoneflies	Nemouridae	7
Caddisflies	Rhyacophilidae, Polycentropidae, Limnephilidae	
Snails	Neritidae, Viviparidae, Ancylidae	
Caddisflies	Hydroptilidae	
Mussels	Unionidae	
Shrimps	Corophiidae, Gammaridae	6
Dragonflies	Platycnemididae, Coenagriidae	
Water Bugs	Mesoveliidae, Hydrometridae, Gerridae, Nepidae, Naucoridae, Notonectidae, Pleidae, Corixidae	
Water Beetles	Haliplidae, Hygrobiidae, Dystiscidae, Gyrinidae, Hydrophilidae, Clambidae, Helodidae, Dryopidae, Elminthidae, Chrysomelidae, Curculionidae	
Caddisflies	Hydropsychidae	
Craneflies	Tipulidae	5
Blackflies	Simuliidae	
Flatworms	Planariidae, Dendrocoelidae	
Mayflies	Betidae	
Alderflies	Sialidae	4
Leeches	Piscicolidae	
Snails	Valvatidae, Hydrobiidae, Lymnaeidae, Physidae, Planorbidae	
Cockles	Sphaeriidae	
Leeches	Glossiphoniidae, Hirudidae, Erpobdellidae	3
Hoglouse	Asellidae	
Midges	Chironomidae	2
Worms	Oligochaeta (whole class)	1

***Source:** Suleiman and Abdullahi [33]*

Table 4: *Summary of aquatic macroinvertebrate communities present in Nzovwe stream*

	Sampling sites													
Invertebrates	1	2	3	4	5	6	7	8	9	10	11	12	13	Total	Percentage
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
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 5: *Taxa of aquatic macroinvertebrates collected from Nzovwe stream*

Invertebrates	Class	Order	Family
Dragonfly nymphs	Insecta	Ordonata	Gomphidae, Libelluloidea
Adult dragonflies	Insecta	Ordonata	Gomphidae, Libelluloidea
Water striders/water skaters	Insecta	Hemiptera	Gerridae
Lesser water boatman	Insecta	Hemiptera	Corixidae
Pouch snails	Gastropoda		Physidae
Predaceous diving beetles	Insecta	Coleoptera	Dytiscidae
Creeping water bugs	Insecta	Hemiptera	Naucoridae
Damselfly nymphs	Insecta	Odonata	Coenagrionidae, Calopterygidae
Stonefly nymphs	Insecta	Plecoptera	Capniidae, Leuctridae, Chloroperlidae
Crane flies	Insecta	Diptera	Tipulidae
Midges	Insecta	Diptera	Chironomidae
Mayfly larva	Insecta	Ephemeroptera	Baetidae, Caenidae, Polymitarcidae
Riffle beetles	Insecta	Coleoptera	Elmidae
Water scavenger beetles	Insecta	Coleoptera	Hydrophilidae
Giant water bugs	Insecta	Hemiptera	Belostomatidae
Crawling water beetles	Insecta	Coleoptera	Haliplidae
Backswimmers	Insecta	Hemiptera	Notonectidae

Table 6: *Biological scores allocated to groups of aquatic macroinvertebrates collected from Nzovwe stream*

Invertebrates	Points/scores
Ephemeroptera: Polymitarcidae	5
Ephemeroptera: Caenidae	4
Ephemeroptera: Baetidae	4
Ordonata: Coenagrionidae	8
Ordonata: Calopterygidae	8
Ordonata: Libellulidea	8
Ordonata: Gomphidae	8
Hemiptera: Corixidae	3
Hemiptera: Gerridae	3
Hemiptera: Belostomatidae	3
Hemiptera: Naucoridae	3
Hemiptera: Notonectidae	3
Gastropoda: Physidae	3
Plecoptera: Chloroperlidae	10
Plecoptera: Capniidae	10
Plecoptera: Leuctridae	10
Diptera: Tipulidae	5
Diptera: Chironomidae	2
Coleoptera: Dytiscidae	3
Coleoptera: Elmidae	5
Coleoptera: Hydrophilidae	3
Coleoptera: Haliplidae	4
Total	115

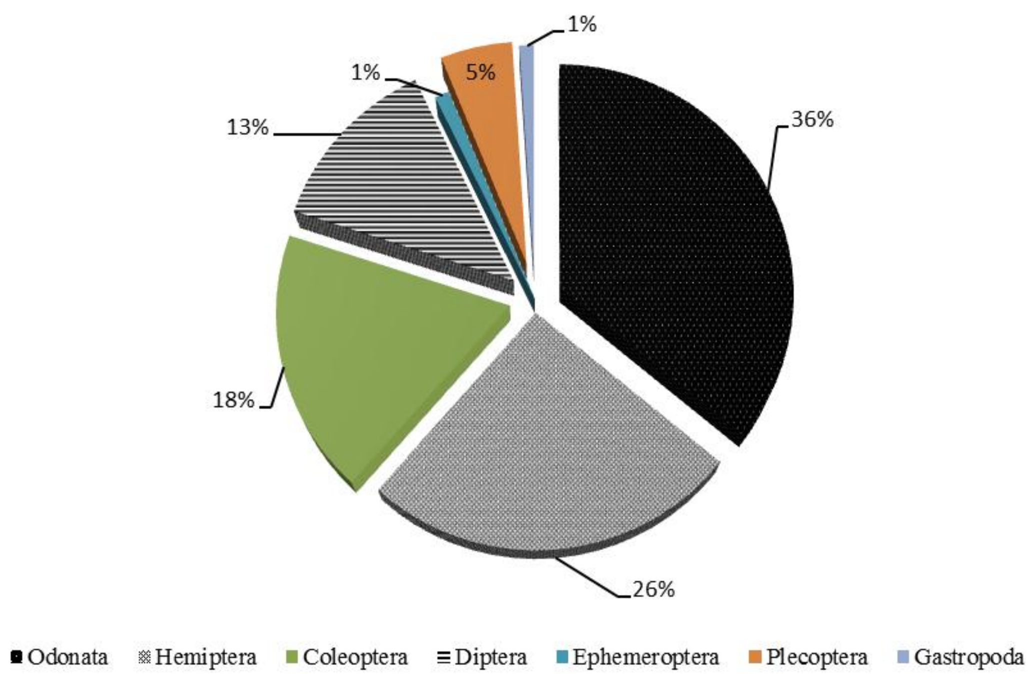

Fig. 3 *Abundance of macroinvertebrates collected from Nzovwe stream*

Table 7: *Three groups of macroinvertebrates based on water pollution tolerance: Pollution-sensitive, somewhat pollution tolerant and pollution-tolerant organisms*

Group	Collected macroinvertebrates	Total No. of species	Abundance in %
Pollution-sensitive organisms	Mayfly larva	6	1.03
	Stonefly nymphs	30	5.14
	Riffle beetles	6	1.03
Total		42	7.19
Somewhat pollution tolerant	Crane fly	48	8.22
	Dragonfly	159	27.23
	Damselfly	51	8.73
	Predaceous diving beetles	42	7.19
	Crawling water beetles	27	4.62
	Water scavenger beetles	33	5.65
Total		360	61.64
Pollution-tolerant organisms	Pouch snails	6	1.03
	Midges	27	4.62
	Giant water bugs	3	0.51
	Backswimmers	3	0.51
	Water striders	77	13.18
	Creeping water bugs	60	10.27
	Water boatman	6	1.03
Total		182	31.16
Total No. of all Invertebrates		584	

4. Discussion

Characteristically, the Nzovwe stream is dominated by group of macroinvertebrate such as Crane fly, Dragonfly, Damselfly, Predaceous diving beetles, Crawling water beetles and Water scavenger beetles (Table 7). These kinds of macroinvertebrates are moderately pollution-sensitive organisms or somewhat pollution tolerant macroinvertebrates [30]. They can survive in fair water quality because their habitat requirements are not as strict as pollution-sensitive organisms such as mayfly (Ephemeroptera) and Stonefly (Plecoptera) [35, 36]. Hence, according to Camargo et al., [37] and Capitulo [38] these macroinvertebrates indicate that the aquatic environment of Nzovwe stream is moderately polluted. Additionally, the large abundance of moderately pollution-sensitive organisms (61.64%) in Nzovwe stream portray that the stream is not clean but moderately polluted aquatic ecosystem (Table 7). On the other hand, macroinvertebrates which are very sensitive to pollution or organisms that requires good water quality (i.e. clear or non-turbid waters and or high dissolved oxygen levels) to survive are less abundant (7.19%) (Table7). This shows that the water quality of Nzovwe stream in studied sites does not support the macroinvertebrates that requires a very clean water to survive except only in site 7 and 11 where a large number of stoneflies were recorded. Based on the BMWP score of Nzovwe stream which is 115 (Table 6), the ecosystem health of this stream can be placed into the category of ¨good' in class I (Table 1). Since the BMWP score of the stream is between 101 and 150, it can be interpreted as "clean or not significantly altered" aquatic ecosystem. This means that the water of Nzovwe stream is not very clean (>150). This interpretation is mirrored by the large number of somewhat pollution tolerant macroinvertebrate (61.64%) and pollution-tolerant macroinvertebrates (31.16%) (Table 7) collected from the stream. Similarly the stream is not significantly altered because it supports some macroinvertebrate individuals which are sensitive to pollution [36, 39]. Therefore, the water of Nzovwe stream can be interpreted as being moderately polluted based on the number of moderately pollution-sensitive organisms and BMWP score [34]. This result is supported by a recent study by Ojija [15] on analysis of water quality of Nzovwe stream by using physico-chemical parameters. He found that the stream is moderately polluted because some parameters were beyond the limit set by Tanzania Bureau of standards [14] and World Health Organization [40] for the standards of water quality. The water of Nzovwe stream being not very clean can be due to non-point source pollution [40] because the stream receives a lot of wastes from several sources. These wastes (garbage, refuse, and/or rubbish) mainly come from neighbouring households and some are delivered by small streams during rainy seasons. Agricultural activities, washing and bathing alter physico-chemical parameters of the stream and hence changing the abundance of macroinvertebrates as well as the quality of water [15, 41, 42]. Farming activities nearby the stream causes soil erosion and consequently increasing suspended particles into the stream. Farming that employs the use of synthetic fertilizers, pesticides, and weedicides; and settlements that demand space are another factors contributing to pollution of the aquatic environment of Nzovwe stream. Kripa et al., [10] argued that human intervention in the name of development has largely affected many natural aquatic ecosystems over the world. This is not far from what is affecting and facing the ecosystem of Nzovwe stream. Site 7 and 11 have at least a good water quality than other sites because the two sites had >5 stoneflies, macroinvertebrates which are very sensitive to water pollution. This is supported by our observation during macroinvertebrate sampling because we noticed no sign of human activities such as farming, washing or bathing. Additionally there was no waste left in the two sites compared with other sites. This is because the sites were not easily accessed by residents due to their deepness and tall grasses that hinder local residents to perform their domestic activities in the two sites. However, it was suspected that pollutants in the two sites may be delivered from other sites or areas during rainy season or through small streams entering the stream.

5. Conclusion and recommendation

The status of water quality of Nzovwe stream is not very clean because its aquatic environment is moderately polluted. This may be dangerous to aquatic fauna and flora that need very clean water to survive. If not well monitored the stream may also pose health risks to local residents who use the stream water for different domestic purposes. Therefore, this study recommends that the relevant authorities should regularly monitor and control the source of pollutants. Additionally, the study recommends that biological indicators and their indices should be adopted for use by relevant authorities as tools for assessing the condition of rivers and other streams in Tanzania. Moreover, due to increase in the number of settlements and waste disposal around the Nzovwe stream in recent years, the stream should be protected and monitored regularly.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgements

This research was partially supported by Mbeya University of Science and Technology (MUST). We would like to thank our colleagues from the Department of Science Mr Christopher Ngimba and Mr Mesfin Gabrehiwot for their comments that greatly improved the manuscript. We would also like to show our gratitude to students of Laboratory Science and Technology for their participation during sampling, collection, and identification of macro invertebrates. Lastly, our sincere thanks go to laboratory technicians at Mbeya University of Science and Technology for their support.

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