DISTRIBUTION AND DIVERSITY OF AQUATIC MACROINVERTEBRATE ASSEMBLAGES IN NYIKA AND VWAZA RESERVES IN MALAWI

A REPORT SUBMITTED TO NYIKA AND VWAZA TRUST (UK)

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Introduction

It is widely recognised that freshwater macroinvertebrate assemblages have intrinsic importance for the broader landscape, by maintaining water quality by processing organic matter, providing key food items for ecologically-important fish species, and representing an important source of food for many riparian terrestrial species (e.g. birds, mammals, lizards and spider). However, the composition and intrinsic ecological importance of these assemblages is often overlooked. This is despite their value as a broad indicator of ecosystem health, and the clear threats imposed by pollution and environmental change.

Macroinvertebrates are a fundamental component of freshwater food webs. They key sources of food for fish and other vertebrates and are also responsible in controlling algal growth (Woodward et al. 2008). Furthermore, macroinvertebrates play a key role in nutrient cycling in aquatic ecosystems since they are primary processors of organic detritus (Wallace & Webster 1996). Thus, diverse macroinvertebrate communities are essential to the functioning and resilience of freshwater food webs and ecosystems (Hagen et al. 2012).

Environmental factors, including temperature, oxygen, flow velocity, substrate composition and macrophyte cover are strongly linked to the composition and abundance of stream biological communities (Richards et al. 1993). Moreover, the distribution of macroinvertebrates is impacted by chemical and physical disturbance linked to human activities such as deforestation, construction, irrigation, agriculture, drainage and waste disposal. The wide array of macroinvertebrate families and species found in streams and rivers have diverse tolerances to these environmental stresses and therefore present a spectrum of responses. This has enabled them to be widely used as indicators of water quality in river management.

Justification for the study

In Malawi, there have been few studies of freshwater macroinvertebrates (Chirwa and Chilima 2017), with much of that work focused on the Lake Malawi fauna (e.g. Abdallah and Barton 2003). More generally, biological studies on streams and river systems have tended to focus on fish (e.g. Sungani et al. 2016). Thus, how environmental changes impact on the biology of flowing waters of Malawi are not well understood. A more developed understanding of Malawi's freshwater macroinvertebrate fauna is important if invertebrate survey is to be used for monitoring and management of Malawi's waters (Chirwa and Chilima 2017). More

specifically, species lists and core baseline abundance data are required to understand how Malawi's riverine fauna will respond to future environmental change, including within protected reserves. This study aims to provide the first assessment of stream macroinvertebrate faunas of the Nyika and Vwaza reserve region, contributing to core baseline knowledge, and building knowledge and capacity in stream sampling methodology.

Research objectives

In this project, we aimed to undertake a baseline survey of freshwater macroinvertebrates of protected areas in Northern Malawi by a) providing an inventory of the species present, **b)** identifying ecological associations between macroinvertebrate diversity and key habitat variables, **c)** curate the first collection of freshwater macroinvertebrates in Malawi, suitable for later detailed taxonomic investigation. These results and sampling protocol will inform and enable future monitoring of the studied environments.

Key aims of the project:

- To generate baseline information on the species of macroinvertebrates present in the major rivers of the Nyika and Vwaza reserves.
- To determine associations between macroinvertebrates and ecological variables of the Vwaza and Nyika aquatic ecosystems during seasonal extremes (dry and rainy), along land use, and altitude gradients,
- To assess whether macroinvertebrate assemblages of these systems can be monitored to provide evidence environmental change.

Research Outputs

The project was intended to produce five key outputs:

i) A report on the diversity of freshwater macroinvertebrate diversity at each of the sampling locations, and the methods for sampling and analysing those results.

ii) A comprehensive checklist of aquatic invertebrates from Nyika

iii) A scientific paper on the key factors structuring the freshwater macroinvertebrate assemblages.

iv) A detailed methodology, that can be followed by researchers, educators and professional environmental scientists including conservation managers.

v) A curated macroinvertebrate collection that can be used for future research and training.

Field Collections research team

The fieldwork for this research study was conducted by the Monkey Bay Fisheries Research Unit, led by Dr Harold Sungani and Dr Maxon Ngochera. Data collected included macroinvertebrates and key water quality parameters. As a condition to sampling permit by Department of Parks and Wildlife, the team was advised to include a research officer and ranger from each reserve. In addition, the team was also joined by 11 students from University of Livingstonia and Lilongwe University of Agriculture and Natural Resources (LUANAR) during Nyika sampling. The students were on attachment for three months at Nyika Reserve. During the fieldwork the students participated in all sampling protocols, enabling them to include the work in their final report after return to LUARAR.

Methods and approaches

The field sampling was conducted in June at the end of the rainy season in Malawi. The aim was to sample the main perennial rivers and lakes of Nyika National Park (Lake Kaulime, North Rumphi River, Chilinda River, Runyina River, North Rukuru River) and Vwaza Reserve (Lake Kazuni, Luwewe River, South Rukuru River). A total of thirteen (13) sites were sampled within the Nyika and Vwaza reserves (Table 1; Figure 1), using equipment listed in Table 2.

Each site was 50m wide, and on arrival all the biotopes in the habitat were identified [Stones (2-25cm), Gravel (stones <2cm), Sand, Mud or Vegetation) and their percentage cover was estimated. For each benthic habitats, the net was placed in the flow, and the substrate kicked/disturbed for a period of 2 minutes. Additionally, hand-picking was done for 1 minute, enabling the collection of snails, for example. Water quality variables were also collected. For vegetation, the net was swept for a period of 2 minutes. Collected samples were placed in 15 litre plastic buckets. The samples were then washed with water through a 500µm sieve to remove silt and other fine sediment. Large sticks and stones were rinsed over the sieve and removed. The clean samples were then placed in 1 litre plastic pots and ethanol was added to fix the samples. The site name, date, immediate terrestrial habitat and geographical position were recorded. In each location water physicochemical parameters were recorded (temperature, oxygen, conductivity). All macroinvertebrate samples were preserved in 40% formalin and taken to the Fisheries Research Station laboratory in Monkey Bay for sorting, identification under magnification. Macroinvertebrates were identified to at least family level (Table 3), and to genus and species where possible) using appropriate keys and photographic guides.

Diversity was compared across samples and habitats using standard biodiversity indices (Table 5). To compare the environmental similarity of the sampled habitats, we used a Principal Component Analysis based on a correlation matrix. To compare the macroinvertebrate community structure among the rivers and habitats we used a Principal Coordinate Analysis, based on a Euclidean distance matrix based on the family-level counts. To test for associations between macroinvertebrate community structure and environmental variables, used redundancy analysis (RDA, Yadamsuren et al. 2020). These analyses were conducted in R (R Core Team 2019), using the packages vegan 2.5-7 (Oksanen et al. 2020) and indicspecies 1.7.9 (De Caceres & Legendre 2009).

Specimens collected have been catalogued and archived at the Fisheries Research Unit, where they can serve as a reference collection for future work, including training in macroinvertebrate identification, future systematic work quantifying the diversity of Malawi's freshwater fauna.

Table 1: Summary of locations of field sampling stations sampled in Nyika and Vwaza reserves in June 2021.

Reserve	**Site**	**Latitude (decimal °)**	**Longitude (decimal °)**	**Elevation (metres)**
Nyika	Chelinda River #1	-10.578	33.808	2278
	Chelinda River #2	-10.587	33.811	2275
	Chelinda River #3	-10.594	33.810	2265
	Lake Kaulime	-10.577	33.759	2343
	North Rukuru River #1	-10.474	33.765	2208
	North Rukuru River #2	-10.476	33.763	2202
	North Rukuru River #3	-10.473	33.766	2207
	North Rumphi River	-10.495	33.885	2087
	Runyina River #1	-10.690	33.637	1904
	Runyina River #2	-10.730	33.682	1786
Vwaza	Lake Kazuni	-11.135	33.650	1082
	Luwewe River	-11.193	33.470	1093
	South Rukuru River	-11.136	33.657	1074

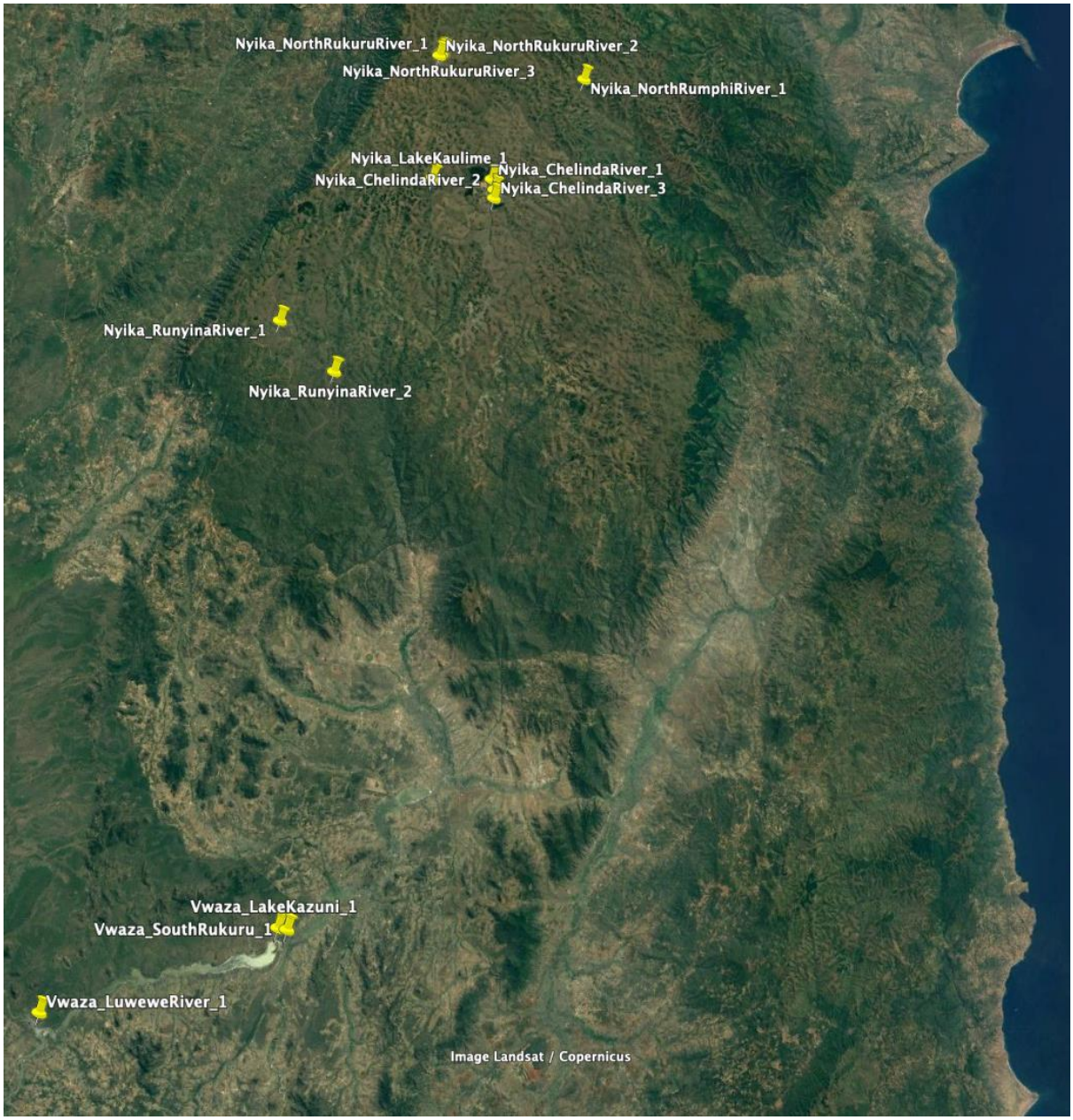

Figure 1: Sampling locations for Nyika and Vwaza Reserves

Table 2: List of materials that were used for sample collection and storage

Material	Use during sampling
Sieves	Sieving substrate samples
Macroinvertebrate / Zooplankton nets	For kick sampling/collection of macroinvertebrates sample
Grab sampler	Collection of bottom substrates for other bottom fauna observation and soil profiling
1000ml Sampling bottles	Collection of both macroinvertebrates' samples and substrate samples
Ziploc bag	Collection of benthic samples
CTD/6600V2 Multiparameter water quality sonde	Measurement of physio-chemical water parameters
Nikon Camera	Capturing sample and/or field work pictures
Garmin GPS receiver	Geographic coordinates
DR 900 Portable photometer	Measuring of other water quality parameters
Absolute /Isopropyl alcohol	Preservation of samples
Dry cells	Back up for portable photometer
Labelling tape	Labeling samples
Neo gloves	
Plastic buckets	Used for holding macroinvertebrates samples
Field notebooks	Writing materials
Pencils	Writing materials
Chest waders	Protective wear for sample collection
Distilled water	Cleaning/rinsing sampling equioments
Formalin (40%)	Fixing samples
D-Frame sampler	Collection of macroinvertebrates samples
Parafilm goose	Sealing of sampling bottles
Dissecting kit	
Laundry bleach	Cleaning sampling equipment

RESULTS

Samples were collected from 13 locations, including Nyika National Park (n=10) and Vwaza Game Reserve (n=3)

Table 3: Families of macroinvertebrates sampled from Nyika and Vwaza freshwaters

Site	**Chelinda River #1**	**Chelinda River #2**	**Chelinda River #3**	**Lake Kaulime**	**North Rukuru River #1**	**North Rukuru River #2**	**North Rukuru River #3**	**North Rumphi River**	**Runyina River #1**	**Runyina River #2**	**Lake Kazuni**	**Luwewe River**	**South Rukuru River**
Aeshnidae	0	0	3	0	1	0	8	0	0	0	0	0	0
Ampullariidae	0	0	0	0	0	0	0	0	0	0	5	10	0
Aselliidae	0	0	0	0	0	0	0	0	0	0	0	0	1
Baetidae	10	0	6	0	45	0	0	24	19	1	0	0	4
Belostomatidae	0	0	0	0	0	9	0	0	0	0	0	5	127
Caenidae	0	0	0	0	0	0	0	0	0	0	0	1	0
Calopterygidae	0	0	0	0	0	2	0	0	0	0	0	0	0
Calamoceratidae	0	0	0	0	0	0	0	0	9	0	0	0	0
Ceratopogonidae	0	0	0	0	0	1	7	0	0	0	0	0	1
Chironomidae	0	0	3	36	0	0	9	2	0	0	0	0	5
Corduliidae	0	0	0	0	0	0	1	0	0	0	0	0	0
Corixidae	0	0	0	168	0	0	0	0	0	0	0	0	0
Crambidae	0	0	0	0	0	0	2	0	0	0	0	0	0
Culicidae	0	0	0	0	0	0	0	0	0	2	0	0	0
Dixidae	0	0	1	0	0	0	0	0	0	0	0	0	0
Dytiscidae	3	0	10	2	0	2	0	8	2	0	16	22	20
Elmidae	11	35	1	0	2	1	0	9	20	6	0	0	1
Gerridae	0	0	1	33	0	0	4	4	3	0	22	0	12
Gomphidae	0	0	22	11	0	0	6	0	0	10	0	0	0
Gyrinidae	0	0	0	0	0	0	0	0	29	0	0	0	0
Haliplidae	0	0	0	0	0	6	0	0	0	2	0	0	0
Heptageniidae	0	0	0	0	6	0	0	0	0	1	0	0	0
Hydrochidae	0	0	0	0	0	1	0	0	0	0	0	16	0
Hydrophilidae	0	0	0	1	0	6	0	0	4	0	17	0	0

Table 3 (continued)

Site	Chelinda River #1	Chelinda River #2	Chelinda River #3	Lake Kaulime	North Rukuru River #1	North Rukuru River #2	North Rukuru River #3	North Rumphi River	Runyina River #1	Runyina River #2	Lake Kazuni	Luwewe River	South Rukuru River
Hydropsychidae	0	0	16	0	11	0	6	0	10	0	21	0	32
Leptoceridae	0	0	0	0	0	0	0	0	0	1	0	0	0
Lestidae	2	0	38	7	14	0	54	12	8	13	0	0	13
Libellulidae	20	2	8	0	0	0	10	9	1	1	2	0	3
Limnichidae	0	0	0	0	0	0	0	1	0	0	0	22	0
Lymnaeidae	0	0	0	0	0	1	0	0	0	0	0	0	0
Macromiidae	0	0	0	0	0	0	0	0	0	0	1	0	0
Nemouridae	0	0	0	0	0	0	0	0	0	1	0	0	0
Nepidae	0	0	0	0	0	0	0	0	0	0	0	0	4
Notonectidae	0	0	1	11	0	11	0	0	0	0	17	2	19
Noteridae	0	0	3	0	0	0	0	0	0	0	0	0	9
Oligochaeta	0	0	0	0	0	1	0	0	1	0	0	0	1
Perlidae	0	0	0	0	6	0	0	10	0	0	0	0	0
Philopotamidae	0	0	5	0	0	0	22	0	0	0	4	0	0
Pleidae	0	0	0	0	0	0	0	0	0	0	5	0	0
Polycentropodidae	2	0	0	0	0	0	0	23	0	0	0	0	0
Potamonautidae	1	0	0	0	1	0	2	0	0	0	0	0	0
Psephenidae	0	0	0	0	0	0	0	1	0	0	0	0	0
Scirtidae	2	0	0	0	0	0	0	0	0	0	0	0	0
Simuliidae	0	0	1	0	0	0	1	0	0	10	0	0	1
Sphaeriidae	0	0	0	0	0	4	0	7	14	21	4	0	0
Tetragnathidae	0	0	0	0	0	0	0	0	0	0	1	0	0
Tipulidae	2	0	3	0	2	0	8	1	0	1	0	0	0
Unionidae	0	0	3	0	0	0	0	0	0	1	0	0	5
Veliidae	0	0	0	0	0	0	0	0	0	1	39	1	83
Viviparidae	0	0	0	0	0	0	0	0	0	0	1	0	1

Table 4: Environmental variables measured at the survey locations

Site	Region	Elevation (M)	Temp (C)	SpCond (uS)	Sal (ppt)	Depth (M)	pH	pH (mV)	TSS (mg/L)	Turbid+ (NTU)	Chl (ug/L)	Chl RFU	ODOsat %	ODO (mg/L)	BGA-PC	BGA-PC RFU	Veg %	GSM %	Stones %
Chelinda River #1	Nyika	2278	12.82	3.00	0.00	0.84	6.00	246.23	3.00	2.21	0.42	0.08	82.15	8.69	77.62	0.04	4	96	0
Chelinda River #2	Nyika	2275	13.19	2.07	0.00	1.36	5.90	224.69	4.00	6.67	14.26	2.77	87.29	9.16	4691.66	2.23	4	96	0
Chelinda River #3	Nyika	2265	13.36	4.26	0.00	0.78	6.10	236.75	5.00	1.11	0.42	0.08	84.47	8.83	138.41	0.07	4	96	0
Lake Kaulime	Nyika	2343	15.13	258.15	0.12	1.97	5.10	195.23	26.00	2.11	1.19	0.23	68.82	5.16	519.45	0.25	20	80	0
North Rukuru River #1	Nyika	2208	14.60	76.17	0.03	1.55	5.90	191.05	0.00	2.99	0.99	0.19	86.00	8.75	6027.39	2.87	4	0	96
North Rukuru River #2	Nyika	2202	18.30	229.69	0.11	0.80	6.00	182.35	0.00	3.74	2.07	0.40	88.83	8.35	91.69	0.03	4	0	96
North Rukuru River #3	Nyika	2207	13.43	2.50	0.00	0.73	6.00	228.09	0.00	0.34	1.03	0.20	83.32	8.70	128.97	0.06	4	0	96
North Rumphi River	Nyika	2087	17.28	55.48	0.03	1.50	6.10	240.75	14.00	2.78	0.60	0.12	83.74	8.05	2183.00	1.04	10	90	0
Runyina River #1	Nyika	1904	12.84	3.84	0.00	2.40	6.10	194.40	6.00	5.53	0.75	0.14	87.55	9.26	390.16	0.18	90	5	5
Runyina River #2	Nyika	1786	13.36	0.14	0.00	3.15	6.10	188.62	9.00	1.50	0.66	0.13	87.40	9.14	1020.05	0.49	90	5	5
Lake Kazuni	Vwaza	1082	21.41	142.59	0.07	0.70	7.00	120.29	127.00	396.04	15.44	2.99	100.25	8.86	4890.07	2.33	90	10	0
Luwewe River	Vwaza	1093	23.85	101.65	0.05	0.67	6.60	120.18	60.00	1005.97	25.23	4.89	117.09	9.88	12549.52	5.97	90	10	0
South Rukuru River	Vwaza	1074	20.24	192.80	0.09	4.63	6.70	124.31	75.00	152.96	9.08	1.76	98.98	8.95	1833.94	0.87	90	10	0

In total 18 environmental variables were recorded from each of the 13 sites. A Principal Component Analysis clearly distinguished the habitats in the two reserves, with the primary axis of environmental variation PC1, capturing 48.5% of the observed variation, and the next axis PC2 captured 19.9% of the variation (Figure 2). Sites in Vwaza National Park (positive PC1 scores) were characterized by a low elevation, greater density of suspended solids, greater turbidity, higher alkalinity (pH) and greater vegetation coverage (Table 4). Sites in Nyika National Park (negative PC1 scores) were characterized by a high elevation, greater density of suspended solids, greater turbidity, higher alkalinity (pH) and greater vegetation coverage (Table 4).

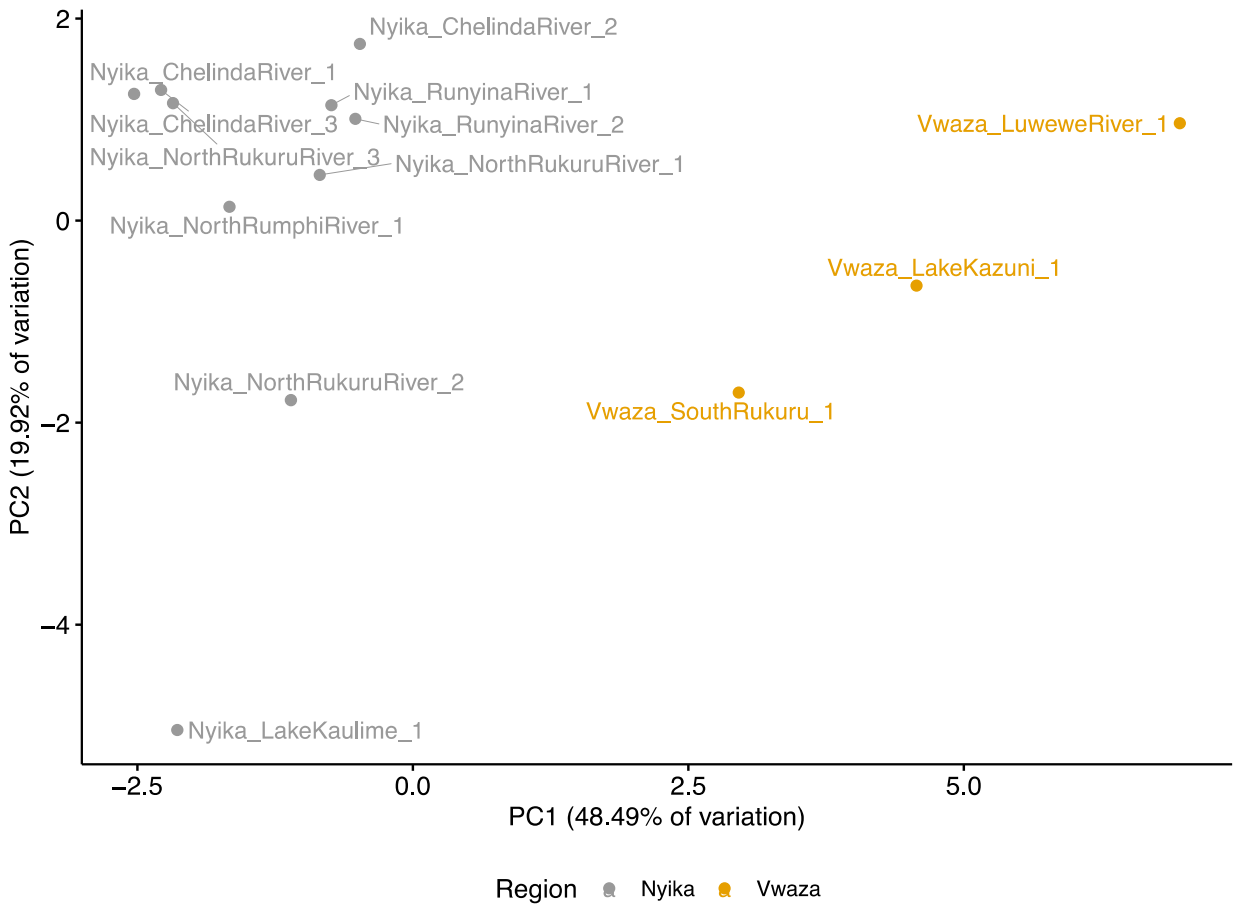

Figure 2. Principal Component Analysis of the environmental variables. Filled circles indicate the sampling locations, and closer symbols indicate more environmentally similar locations.

In total macroinvertebrates belonging to 50 different taxa were identified across the 13 sites (Table 3; most at family level). Sites in Vwaza had marginally higher diversity, in terms of families present (Taxa_S; Table 5).

Table 5: Mean diversity of macroinvertebrates in samples

Diversity Index	Nyika (average of index)	Vwaza (average of index)
Taxa_S	11.100	13.667
Dominance_D	106.000	192.000
Simpson_1-D	0.282	0.191
Shannon_H	0.718	0.809
Evenness_e^H/S	1.755	1.941
Brillouin	0.593	0.559
Menhinick	1.585	1.816
Margalef	1.160	1.017
Equitability_J	2.228	2.422
Fisher_alpha	0.730	0.767
Berger-Parker	3.507	3.431
Chao-1	0.414	0.300

A Principal Coordinates Analysis of the abundance data ($\log_{10}$ transformed, Euclidean distances) revealed the major axes of variation PCoA1 and PCoA2 largely separated the Nyika and Vwaza sites (Figure 3). There was a highly significant difference in the community structure of macroinvertebrates between Vwaza and Nyika (Permanova; $\log_{10}$ transformed data, Euclidean distances, $F = 2.537$, $P = 0.008$). There was a highly significant association between environmental variables (PC1, PC2) and community structure across all sites. (Anova - RDA, $F_{2,10} = 2.153$, $P < 0.001$).

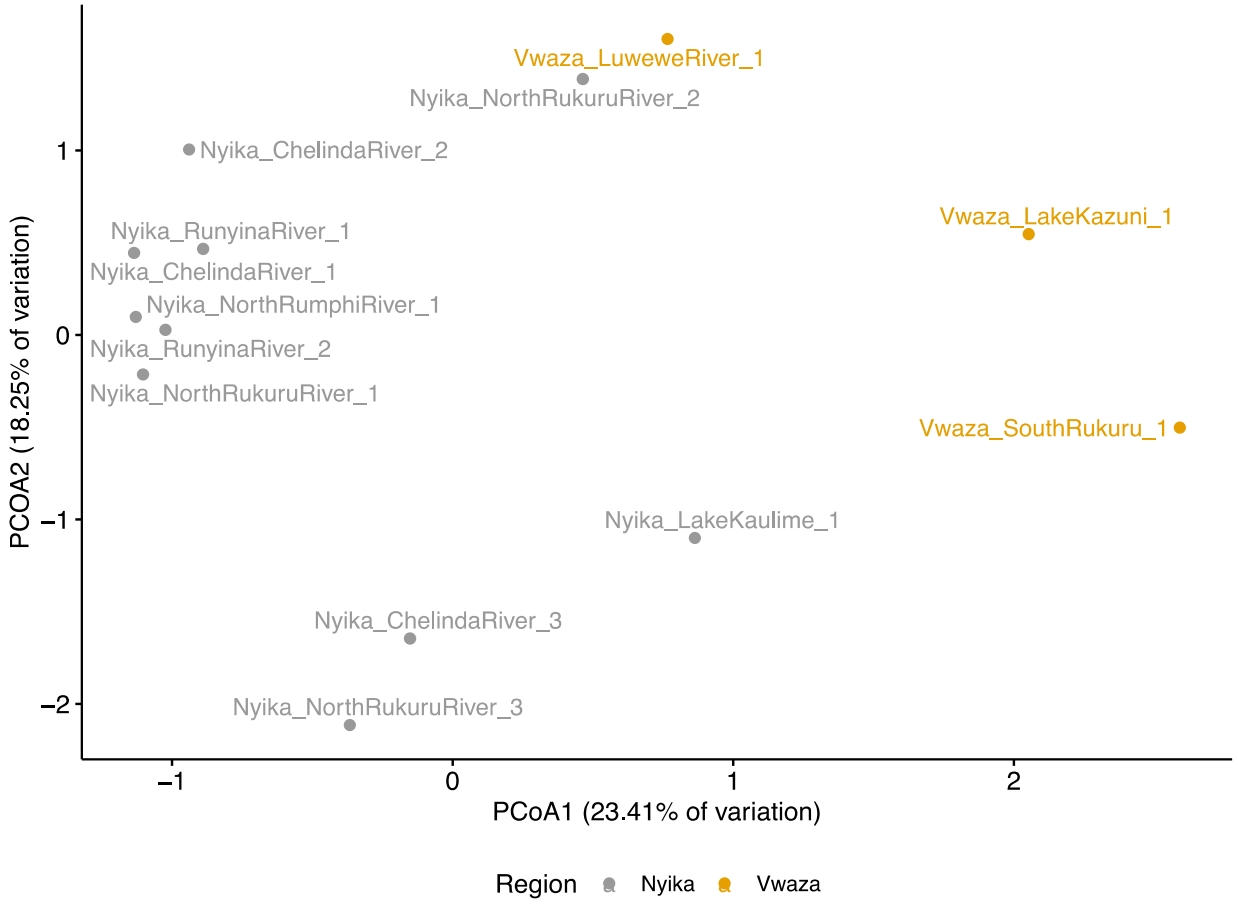

Figure 3. Principal Coordinates Analysis of the macroinvertebrate data (family level counts), with closer points indicating more similar macroinvertebrate communities.

An indicator analysis enabled us to identify the key distinguishing taxa between the Nyika and Vwaza sites, taking into account abundance and frequency of occurrence (Table 6). The Veliidae (riffle bugs), Belestomatidae (giant water bugs), Dytiscidae (predatory diving beetles) and Ampullariidae (apple snails) and Viviparidae (mystery snails) were more prevalent in Vwaza. The Lestidae (spread winged damselflies), Baetidae (small mayflies), Libellulidae (percher dragonflies), Tipulidae (crane flies) and Elmidae (riffle beetles) were more prevalent in Nyika (Table 6).

Table 6: Indicator value of individual families. Potential indictor species (with indicator value statistics > 0.7) are highlighted in bold.

Family	Nyika (mean individuals in sample)	Vwaza (mean individuals in sample)	Indicator value statistic
Aeshnidae	1.200	0.000	0.548
Ampullariidae	**0.000**	**5.000**	**0.816**
Aselliidae	0.000	0.333	0.577
Baetidae	**10.500**	**1.333**	**0.736**
Belostomatidae	**0.900**	**44.000**	**0.704**
Caenidae	0.000	0.333	0.577
Calopterygidae	0.200	0.000	0.316
Calamoceratidae	0.900	0.000	0.316
Ceratopogonidae	0.800	0.333	0.400
Chironomidae	5.000	1.667	0.574
Corduliidae	0.100	0.000	0.316
Corixidae	16.800	0.000	0.316
Crambidae	0.200	0.000	0.316
Culicidae	0.200	0.000	0.316
Dixidae	0.100	0.000	0.316
Dytiscidae	**2.700**	**19.333**	**0.702**
Elmidae	**8.500**	**0.333**	**0.875**
Gerridae	4.500	11.333	0.551
Gomphidae	4.900	0.000	0.632
Gyrinidae	2.900	0.000	0.316
Haliplidae	0.800	0.000	0.447
Heptageniidae	0.700	0.000	0.447
Hydrochidae	0.100	5.333	0.518
Hydrophilidae	1.100	5.667	0.423
Hydropsychidae	4.300	17.667	0.520
Leptoceridae	0.100	0.000	0.316
Lestidae	**14.800**	**4.333**	**0.843**
Libellulidae	**5.100**	**1.667**	**0.764**
Limnichidae	0.100	7.333	0.522
Lymnaeidae	0.100	0.000	0.316
Macromiidae	0.000	0.333	0.577
Nemouridae	0.100	0.000	0.316
Nepidae	0.000	1.333	0.577
Notonectidae	**2.300**	**12.667**	**0.743**
Noteridae	0.300	3.000	0.456
Oligochaeta	0.200	0.333	0.365
Perlidae	1.600	0.000	0.447
Philopotamidae	2.700	1.333	0.388
Pleidae	0.000	1.667	0.577
Polycentropodidae	2.500	0.000	0.447
Potamonautidae	0.400	0.000	0.548
Psephenidae	0.100	0.000	0.316
Scirtidae	0.200	0.000	0.316
Simuliidae	1.200	0.333	0.504
Sphaeriidae	4.600	1.333	0.585
Tetragnathidae	0.000	0.333	0.577
Tipulidae	**1.700**	**0.000**	**0.775**
Unionidae	0.400	1.667	0.393
Veliidae	**0.100**	**41.000**	**0.963**
Viviparidae	**0.000**	**0.667**	**0.816**

Discussion

Stream health assessments can be determined by considering the type and abundance of the taxa present. For example, pollution sensitive species are highly sensitive to organic pollution as they only thrive in environments with higher dissolved oxygen, neutral pH and cold water (Henriques-de Oliveira et al. 2007; Narangarvuu et al. 2014). On the other hand, pollution tolerant species are insensitive to various environmental stressors, allowing them to thrive even in heavily degraded habitats. From the results both Nyika and Vwaza seem to be dominated by a mixture of pollution sensitive and somewhat pollution tolerant, an indication that the two environments are still in pristine state. The abundance of pollution sensitive orders including the Ephemeroptera (mayflies) and Odonata (damselflies and dragonflies) implies both reserves are heavily insulated from local anthropogenic activities can be major sources of organic pollution.

The results revealed a highly significant difference in the community structure of macroinvertebrates between Vwaza and Nyika Reserves. These results may be attributed to differences in multiple environmental factors between the two reserves. Nyika reserve is situated at an average height of 2155m above sea level while Vwaza is situated at an average height of 1083m (Table 4). The difference in height has a great influence in temperatures, as observed from this study where Nyika had an average water temperature of 14.4^{O}C while Vwaza had an average water temperature of 21.8 ^{O}C (Table 4). Temperature is a major determinant of freshwater invertebrate community structure, with species distributions strongly linked to physiologically-determined thermal tolerances (Woodward et al., 2010).

The results also revealed high concentrations of total suspended solids in water for Vwaza with an average of 87TSS as compared to Nyika with an average of 7TSS (Table 4). From personal observation, Vwaza has fewer sources of water as compared to Nyika. This has resulted in more activities from the animals in the few rivers and the lake. Some of the animals like hippopotamuses have overpopulated Lake Kazuni to the disadvantage of other smaller animals especially during dry season when water levels in the lake are down.

Experiences and challenges learnt

During the sampling period the research team encountered and overcame multiple challenges. This was the first time for most of the researchers to travel to Nyika, and were therefore unfamiliar with the terrain, road conditions, weather conditions, and wildlife. Sampling of macroinvertebrates involves specialized equipment, that can weigh up to 10 kgs. The terrain did not allow vehicles to reach all sampling stations, so researchers necessarily carried the equipment by hand. Fortunately, students from two government Universities were able to join the sampling (Lilongwe University of Agriculture and Natural Resources (LUANAR) and University of Livingstonia), and at that point the load was split among the team.

Vehicles were parked distantly from sampling stations, and the team walked long distances to access stations

During sampling we also encountered road blockages caused by trees dislodged by elephants. This was particularly challenging in Vwaza Marsh, where the roads pass through thick forest. Since the team did not expect such situations (being first travellers in the area), we did not carry pangas or axes to cut the trees in case of such eventualities. Nevertheless, it was possible to find alternative off road routes. During the sampling season, Lake Kazuni water levels were shrinking and we encountered large numbers of hippopotamus in the remnant pools. It was such a great experience to witness such big animals in one place.


The cold weather of Nyika was a challenge and determined the start and finish time of sampling. Temperatures could drop to less than 10°C in the morning and evenings, and researchers aimed to sample waters when they warmer so as to allow most of the invertebrates to be active. We hypothesised that invertebrates would be more easily accessible in water column as they mostly attach to substrates.

The researchers observed a high level of turbidity in the waters of Lake Kazuni as a result of the large population of hippopotamuses inhabiting the lake. These high density of these animals means there is now low levels of aquatic vegetation, presumably due to physical disturbance of the ecosystem. We observed that Lake Kazuni is of central importance to the wildlife of Vwaza, as there are very few river networks within the reserve meaning it is critical water source. We enjoyed meeting and working with experienced rangers in Nyika National Park. Mr Felix Panjani from Chelinda camp and Lucky Kamanga explained the rich history of these two parks. We always felt safe in their presence.

We were pleased to work alongside students from Lilongwe University of Agriculture and Natural Resources (LUANAR). It was a great e practical learning experience for them. The students were exposed to different sampling gear and techniques, and they helped us to obtain more samples that would otherwise be possible.


Conclusion

The results of this research have provided fundamental knowledge on the diversity of species present in the freshwaters and has highlighted the ecosystem services that are provided by the taxa. The results have also provided an opportunity to review the potential for macroinvertebrate monitoring program that will contribute to knowledge of environmental change. The methods used, documents and curated collections will enable staff of conservation organisations to engage with these critical yet largely overlooked components of Malawi's biodiversity.

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APPENDIX

Common macroinvertebrates sampled and photographed during field work

	
Belostomatidae	Belostomatidae
	
Nepidae	Hydropsychidae Larvae
	
Veliidae	Nepidae “Ranatra species”

	
Dytiscidae (*Agabus bipustulatus*)	Dytiscidae
	
Geriidae (Water strider)	*Tetragnatha c.f. guatemalensis*
	
Potamonautidae	Tipulidae

	
Libellulidae nymph	Libellulidae
	
Hydropsychidae larvae	Chironomidae
	
Lestidae	Gomphidae

	
Chironomidae	Corixidae
	
“Psephenidae”	Viviparidae
	
Nepidae. *Ranatra* spp.	Aeshnidae

	
Notonectidae (Back swimmers)	Lestidae larvae (Lestes spp)
	
Veliidae	Heptageniidae
	
Perlidae	Baetidae

	
Caenidae nymph	Gomphidae
	
Leptoceridae	Calamoceratidae
	
Polycentropodidae larvae	Hydrochidae