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Spatial distribution patterns of benthic macroinvertebrate functional feeding groups in two rivers of the Olifants river system, South Africa

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ABSTRACT

Benthic macroinvertebrates play a vital role in ecosystem functioning, such as nutrient cycling, primary production, decomposition and material translocation. A study was done to determine the functional feeding groups (FFGs) distribution along two streams of the Olifants River System, South Africa. There were longitudinal differences of the functional groups but were more pronounced in the Dwars River than in the Spekboom River. Collector-gatherers and collector-filterers were the most abundant groups recorded in both rivers. The least abundant groups were the shredders and scrapers in both rivers. The highest abundance of shredders in both rivers was at upstream sites (DS1 and SS1), more scrapers were found at midstream sites (DS3 and SS2), collector-gatherers and collector-filterers increased in the downstream (SS4) of the Spekboom River and predators were nearly constant in relative abundance at all sites. The relative abundance and richness of the FFGs did not conform completely to the river continuum concept (RCC). This could be related to the degradation of the catchment resulting from human activities which affected the quality of the water.

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Introduction

The rapid economic growth and industrialization in many developing countries is causing pollution of freshwater bodies coupled with inadequate management practices requires an urgent attention. The effluents from various human activities in the catchment of rivers are causing deterioration of river systems (Jooste et al. 2015, Jun et al. 2016, Grizzetti et al. 2017, Addo-Bediako 2020) and may have adverse effects on aquatic biota.

Biological monitoring is one of the methods used to determine the effects of anthropogenic activities on water quality of rivers. It is considered more effective than physico-chemical parameters for monitoring water quality (Gebler et al. 2014) and very useful to obtain ecological information of rivers (Merritt et al. 2017). Benthic macroinvertebrates,

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for example, provide a more precise understanding of changes in aquatic conditions when compared to chemical and microbiological data, which rather present short term fluctuation (Ghasemi and Kamali 2014). Macroinvertebrates also represent an important functional link between basal resources, such as algae and detritus and upper trophic levels, such as fish (Díaz Villanueva et al. 2012).

Functional feeding groups (FFGs) are a classification approach that is based on behavioural mechanisms of food acquisition (Ramirez and Gutiérrez-Fonseca 2014). The FFG approach is used to classify organisms such as, macroinvertebrates, according to their role in the processing of organic matter. Some macroinvertebrates, such as shredders and scrapers are said to be more sensitive to environmental changes, while gatherers and filterers are more tolerant to pollution that might alter the availability of certain food types (Barbour et al. 1996). Thus, FFGs of macroinvertebrates can potentially be used to assess aquatic ecosystem health (Bhawsar et al. 2015). The relative abundance of different functional groups reflects anthropogenic impact on the environment (Merritt et al. 2002, Cummins et al. 2005). Hence, assessing the distribution of FFGs and benthic macroinvertebrate assemblages according to environmental variables are increasingly (Jun et al. 2016, Kim et al. 2016). The FFG approach is considered appropriate and rapid for characterising ecosystem conditions and complements the taxonomical approach (Cummins et al. 2005, Mishra and Nautiyal 2013, Cummins 2016). It is used to assess the effect of land use disturbances on river functioning (De Castro et al. 2016), thus FFG provides a further perspective together with other community indices to ensure a better understanding of the relationship between habitat and aquatic fauna (Townsend et al. 1997). Functional composition is therefore necessary for management actions to enhance ecosystem functioning (Ferreira et al. 2012).

The river continuum concept (RCC) describes the whole river system as a continuously integrating series of physical gradients as it flows from headwater to mouth. Within the stream system, longitudinal connectivity refers to the pathways along the entire length of a stream. The river system is viewed as longitudinally linked systems in which biotic factors are orderly, and ecosystem-level processes in downstream reaches are linked to those in upstream parts of the system. According to the RCC proposed by Vannote et al. (1980), a higher abundance of collector-gatherers and shredders is expected in forested headwaters, which reflects the importance of riparian zone as a source of allochthonous material. The RCC model predicts longitudinal changes in the functional and taxonomic composition of macroinvertebrate communities from the headwater to the mouth (Brasil et al. 2014).

The Steelpoort River sub-catchment of the Olifants River System in South Africa has undergone a rapid land use/land cover change in the last decade mainly due to intensive mining activities and human settlements. This has affected many freshwater streams in the area including Dwars and Spekboom rivers. Knowledge of the functional composition of macroinvertebrates in tropical and subtropical streams is important to understand organic matter processing, energy flow, and trophic relationship and management activities needed to minimize the impairment of ecosystem functioning (Ferreira et al. 2012). The present study was to assess the effects of land use disturbances on the longitudinal distribution of the functional groups of benthic macroinvertebrate communities, to determine if FFG distribution of macroinvertebrate conform to the RCC and to assess the ecological integrity of the Dwars and Spekboom rivers using ratios of numerical abundance of the different FFGs as surrogates for ecosystem attributes (Vannote et al. 1980, Merritt and Cummins 1996). The hypothesis was that due to land use changes affecting the rivers, the macroinvertebrate FFGs would not fully conform to the RCC.

Materials and methods

Study area

The Spekboom river and Dwars river are in the Steelpoort sub-basin of the Olifants river system. The sub-basin lies mainly on an escarpment between 1500 and 2400 m above mean sea level (Stimie et al. 2001). The area is characterized by hills and mountains with mountain grassland, rocky highveld grassland, moist sandy highveld grassland, mixed bushveld and patches of Afro-montane forest. There are extensive mining and industrial activities in the Steelpoort catchment including chrome, coal, granite, magnesite, alluvial gold, platinum and vanadium mines concentrated in the upper sub-catchment (Stimie et al. 2001).

The selected sampling sites were based on land-use activities in the catchments. Four sampling sites were selected along the Dwars River to represent the different land use activities; DS1 is secluded (24.8553 S 30.1022 E) and is near the Tweefontein mine water return dam, DS2 (24.428 S 30.0867 E) is near mining and industrial areas (the ferro-chrome mine and Lion smelter), DS3 (24.83167 S 30.0797 E) is near agricultural activities and DS4 (24.8303 S 30.0794 E) is the confluence of the Dwars River and Steelpoort River, there are agricultural activity and informal settlements near the site. The following four sampling sites were selected along the Spekboom River, SS1, (24.6936 S, 30.3628 E) near mining and agricultural activities, SS2 (24.6679 S, 30.3386 E) near reservoir/water treatment, SS3 (24.6586 S, 30.3244 E) near waste water treatment plants and SS4 (24.6419 S, 30.3078 E) near human settlement and cattle grazing field and it is the confluence of the Spekboom river and Steelpoort river (Figure 1).

Climate of the area is relatively hot and seasonal. The area is characterized by distinct rainy seasons and high ambient temperatures that can be $>30^{\circ}\text{C}$ during the hot months of December to February. Average annual precipitation is about 700 mm and rainfall usually occurs during the summer season.

Seasonal water samples were collected during February, April, July and September (summer, autumn, winter and spring, respectively), 2018. The samples were collected in 1000 ml polyethylene bottles (acid pre-treated) and stored at 4°C prior to analyses. Seasonal environmental variables, such as pH, water temperature, dissolved oxygen (DO), total dissolved solids (TDS) and electrical conductivity (EC) were recorded at the sampling sites using a YSI Model 554 Data logger, for the characterization of each sample point. Laboratory measurements were conducted to determine turbidity and nutrients (NH_4 , NO_2 , NO_3 , and PO_4) using a spectrophotometer (Merck Pharo 100 SpectroquantTM).

Benthic macroinvertebrates were collected using the kick sampling method, whereby sediment and rocks in the water are kicked with feet while sweeping the net to dislodge any attached macroinvertebrates using a hand-held kick net (dimension 30×30 cm, mesh size $500\ \mu\text{m}$) within a 20–30 m reach comprising a relatively homogenous riffle section. Where available, the three major habitats identified by Dickens and Graham (2002) were sampled. These habitats include: stones (including bedrock or any solid object), aquatic vegetation (marginal, floating and submerged) and gravel (including sand mud, silt and clay). Stones were sampled by kicking, dislodging and collecting the macroinvertebrates into the net. A total length of approximately 2 m of aquatic vegetation spread over more locations was sampled by pushing the net vigorously into the vegetation, moving backward and forward. Gravel was stirred by scraping with the feet, whilst sweeping the net over the disturbed area to catch removed biota. The three sub samples from the three habitats were pooled, and macroinvertebrates were identified to family level except in the case of Oligochaeta and Hirudinea which were identified

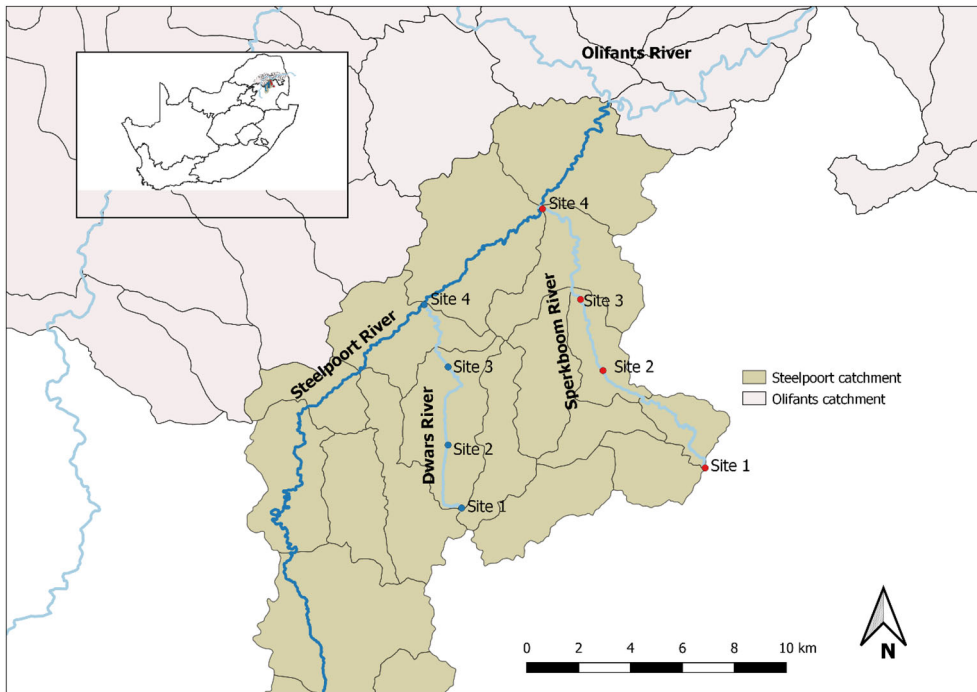


Figure 1. Map of the study area, showing the locations of the sampling sites of the Dwars and Spekboom rivers.

to class level. Benthic samples were preserved in 70% ethanol and were sent to the laboratory.

In the laboratory, all macroinvertebrates were identified to family level using Gerber and Gabriel's field guide manual (Gerber and Gabriel 2002). The macroinvertebrates were then classified into FFGs: Shredders (Sh), Collector-gatherers (CG), Collector-filterers (CF), Scrapers (Sc) and Predators (P), using the criteria of Merritt and Cummins (1996) and Cummins et al. (2005). Shredders are macroinvertebrates that chew conditioned litter or live vascular plant tissue (coarse particulate organic matter); collector-gatherers acquire fine particulate organic matter from interstices in the bottom sediments; collector-filterers capture fine particulate organic matter from the water column using silken nets and filtering fans; scrapers feed on algae attached on stable surfaces and predators feed on living prey. Abundance of aquatic insect FFGs in each site were calculated. The macroinvertebrates used for the study are preserved in the Water Laboratory, University of Limpopo.

The mean and standard deviation for each physicochemical variables of the study sites were calculated. Two-way ANOVAs were used to compare physicochemical variables and FFG abundance among sites and seasons, with FFG numbers being the dependent and site and seasons as independent variables. Canonical Correspondence analysis was used to describe the relationship between the FFG and physicochemical variables. The statistical analyses were conducted using the software package Statistica v10.0. The following diversity indices were also calculated: family richness (S), family richness of Ephemeroptera, Plecoptera and Trichoptera (EPT), Shannon diversity index (H') and average score per taxa (ASPT).

Table 1. The physicochemical variables in water at different sites in the Dwars and Spekboom rivers sampled in February, April, July and September, 2018.

Variables	DS1	DS2	DS3	DS4	SS1	SS2	SS3	SS4
Width (m)	4.92 ± 0.03	8.26 ± 1.21	6.09 ± 0.44	11.0 ± 0.0	4.49 ± 3.18	4.7 ± 2.35	4.1 ± 2.0	5.36 ± 2.3
Depth	0.14 ± 0.02	0.2 ± 0.01	0.13 ± 0.02	0.68 ± 0.21	0.26 ± 0.11	0.19 ± 0.08	0.24 ± 0.21	0.21 ± 0.12
Current (cms ⁻¹)	21.4 ± 13.9	15.7 ± 9.7	24.4 ± 21.3	20.2 ± 20.1	28.4 ± 16.2	17.7 ± 8.6	26.3 ± 20.4	21.9 ± 10.8
Temp (°C)	19.6 ± 3.4	17.5 ± 4.1	21.4 ± 5.2	20.7 ± 6.1	20.1 ± 4.3	20.65 ± 3.1	20.2 ± 3.7	20.7 ± 4.1
DO (mg/l)	9.13 ± 1.7	8.21 ± 2.1	6.8 ± 3.4	7.9 ± 1.4	8.7 ± 0.7	8.8 ± 0.6	6.1 ± 3.1	7.8 ± 1.2
pH	7.5-9.21	7.71-8.69	7.94-8.96	7.53-9.03	6.8-8.67	7.8-8.52	7.64-8.53	7.71-8.56
TDS (mg/l)	261.7 ± 112	308.2 ± 176	321.3 ± 143	273.0 ± 105	243.9 ± 101	264.2 ± 111	356.3 ± 143	271.3 ± 12
EC (mS/m)	529.2 ± 281	531.4 ± 98	547.8 ± 211	421.6 ± 112	393.4 ± 113	449.6 ± 143	575.3 ± 137	428.5 ± 16
Turbidity (NTU)	2.1 ± 1.60	1.4 ± 0.41	5.2 ± 2.30	7.3 ± 2.70	6.8 ± 3.43	2.1 ± 2.0	13.3 ± 7.4	10.3 ± 3.4
Salinity (‰)	0.53 ± 0.12	0.36 ± 0.11	0.37 ± 0.16	0.21 ± 0.10	0.24 ± 0.12	0.22 ± 0.06	0.34 ± 0.11	0.27 ± 0.1
NO ₂ (mg/l)	0.33 ± 0.2	0.03 ± 0.01	0.03 ± 0.02	0.02 ± 0.01	0.03 ± 0.02	0.16 ± 0.09	1.3 ± 1.2	0.7 ± 0.6
NO ₃ (mg/l)	5.8 ± 1.4	5.6 ± 2.3	7.4 ± 3.1	1.9 ± 2.2	0.56 ± 0.02	0.50 ± 0.4	6.3 ± 2.4	1.3 ± 0.8
PO ₄ (mg/l)	0.04 ± 0.01	0.04 ± 0.0	0.05 ± 0.01	0.04 ± 0.02	0.06 ± 0.03	0.09 ± 0.03	2.1 ± 1.1	0.05 ± 0.02

Table 2. Two-way analysis of variance (two-way ANOVA) based on the physicochemical variables and macroinvertebrates (FFG) differences among sites and seasons.

Variables	Season		River		Season × River	
	F	p	F	p	F	p
Temperature	0.139	>0.05	0.139	>0.05	0.362	>0.05
pH	0.665	>0.05	0.070	>0.05	0.547	>0.05
Dissolved oxygen	2.721	>0.05	4.890	<0.05	0.664	>0.05
Conductivity	2.120	>0.05	0.033	>0.05	1.044	>0.05
Total dissolved solids	1.304	>0.05	0.006	>0.05	0.484	>0.05
Turbidity	43.52	<0.001	51.59	<0.001	8.339	<0.001
Nitrate	33.40	<0.001	114.9	<0.001	7.724	<0.001
Phosphate	0.985	>0.05	1.168	>0.05	0.991	>0.05

Results

Physicochemical variables

There were variations in the physicochemical variables between the two rivers (Table 1; Tables S1a and S1b). The mean temperatures ranged from 17.5 to 21.4 °C in Dwars River and 20.1 to 20.7 °C in Spekboom River. The lowest mean DO concentrations of 6.1 ± 3.1 and 6.8 ± 3.4 mg/l were recorded at midstream sites, SS3 and DS3 of Spekboom and Dwars rivers respectively. The highest mean EC (575 ± 137 µS/cm) and TDS (356.3 ± 143 ml/l) were recorded at SS3 of Spekboom River. The pH values ranged from 6.8 to 8.6 in the Spekboom River and 7.5 to 9.2 in the Dwars River. There were no significant differences in temperature, DO, pH, TDS, salinity and phosphates among sites and between rivers (ANOVA, *p* > 0.05). The highest mean turbidity value was recorded at SS3 of the Spekboom River and higher turbidity values were recorded in Spekboom River than Dwars River (ANOVA, *p* < 0.05). The highest mean nitrate concentration was recorded at DS3 and the highest phosphate concentration at SS3.

There were no significant differences in temperature, pH, conductivity, total dissolved solids and phosphates among seasons and between rivers (ANOVA, *p* > 0.05). However, there were significant differences in dissolved oxygen between the rivers. There were significant differences in turbidity and nitrates among seasons, between the rivers and their interactions (ANOVA, *p* < 0.05) (Table 2).

Table 3. Macroinvertebrate diversity and biotic indices for the Dwars and Spekboom rivers recorded in February, April, July and September, 2018.

Site	EPT	ASPT	H'
DS1	12	7.09	2.4
DS2	8	6.24	2.6
DS3	9	6.8	2.4
DS4	6	5.5	2.3
SS1	11	6.09	2.5
SS2	10	4.4	2.6
SS3	8	3.7	2.4
SS4	8	4.2	2.1

Macroinvertebrates

A total of 7,415 individual macroinvertebrates belonging to 33 families and 11 orders were collected in the Dwars River and a total of 11,379 individual macroinvertebrates belonging to 37 families and 12 orders were collected in the Spekboom River (Tables S2a and S2b). In the Dwars River, the dominant taxa were Hydropsychidae (1875), Caenidae (940), followed by Baetidae (810) and then Elmidae (714). While in the Spekboom River, the dominant taxa were Baetidae (1989), Hydropsychidae (1378), followed by Simuliidae (1362) and then Chironomidae (1124). The lowest diversity index ($H' = 2.1$) was recorded at SS4 and the highest ($H' = 2.6$) was recorded at DS2 and SS2. The EPT index for Dwars River ranged from 6 to 12 and in the Spekboom River from 8 to 11. The ASPT ranged from 5.5 to 7.09 at the Dwars River and from 3.7 to 6.09 (Table 3).

In terms of the FFGs, a total of 40 taxa were collected, 18 predators, 8 scrapers, 6 collector-gatherers, 5 collector-filterers, 2 shredders (Table 4).

In the Dwars River, the collector-gatherers made up of 35%, followed by collector-filterer (31%), predator (20%), shredder (10%), and then scraper (4%). In the Spekboom River, the collector-gatherer (41%), followed by collector-filterer (27%), predator (18%), scraper (8%) and then shredder (6%). There were significant variations in terms of distribution of the FFGs between the two rivers (ANOVA: $F = 4.35$, $p < 0.05$). In Dwars River, the highest abundance of all the FFGs was in the upstream, DS1 and the lowest in the downstream, DS4 (Table 5).

The collector-gatherers were the most abundant FFG at all sites in both rivers except at DS1, where the collector-filterers were the dominant group. In the Spekboom River, the highest abundance of the collector-gatherers was recorded at the downstream site, SS4, the highest abundance of the collector-filterers, predators and scrapers were recorded at the midstream site, SS3 and the highest number of shredders was recorded at upstream, SS1 (Figure 2).

The CCA conducted to explore the effects of the physicochemical variables on macroinvertebrate FFGs showed that in the Dwars River pH, turbidity, TDS, EC, DO and depth were the most significant predictors of macroinvertebrate FFG structure, and in the Spekboom River pH, turbidity, TDS, EC and DO were the main predictors of the FFG structure (Figure 3). The association of FFG with environmental variables in the two rivers as revealed by CCA is shown in Table 6. The eigenvalues 0.130, 0.074 and 0.056 for the axis 1, axis 2 and axis 3 explained 50.1%, 78.4% and 100% of variance respectively for the Dwars River. The eigenvalues 0.089, 0.058 and 0.035 for the axis 1, axis 2 and axis 3 explained 48.9%, 80.9% and 100% of variance respectively in the Spekboom River.

There were seasonal variations in the abundance of FFG in both rivers. In the Dwars River, the highest abundance of macroinvertebrates FFG was recorded during winter, followed by summer, autumn and then spring, while in the Spekboom River, the highest

Table 4. Families and the FFGs of macroinvertebrates from Dwars and Spekboom rivers.

Family	DS1	DS2	DS3	DS4	SS1	SS2	SS3	SS4	FFG*
Oligochaeta	13	12	6	8	14	7	15	24	CG
Hirudinea	0	0	0	2	1	11	820	21	P
Perlidae	10	2	2	0	28	45	2	1	P
Notonemouridae	0	0	0	0	1	0	0	0	Sc
Baetidae	468	102	191	49	316	287	439	947	CG
Caenidae	345	83	395	117	154	340	30	244	CG
Heptageniidae	16	13	13	5	102	248	23	8	Sc
Leptophlebiidae	147	79	120	29	59	379	13	6	CG
Oligoneuriidae	4	0	3	0	4	36	4	3	CF
Tricorythidae	25	8	18	0	189	110	11	87	CG
Chlorocyphidae	10	8	19	2	0	37	0	0	P
Coenagrionidae	1	0	1	0	8	24	9	67	P
Gomphidae	419	28	75	41	19	18	7	79	P
Libellulidae	364	7	47	16	18	28	54	98	P
Belostomatidae	1	0	0	1	1	4	11	9	P
Gerridae	0	0	0	0	0	0	0	2	P
Hydrometridae	0	0	0	0	5	0	2	3	P
Nepidae	0	0	0	0	0	15	9	0	P
Naucoridae	3	1	2	4	0	0	0	3	P
Veliidae	0	3	0	0	5	6	1	30	P
Ecnomidae	1	0	0	2	2	0	0	0	CF
Hydropsychidae	1456	119	270	30	360	166	479	373	CF
Leptoceridae	11	0	0	0	6	7	0	0	Sh
Hydroptilidae	2	0	0	0	0	0	0	0	Sc
Dytiscidae	0	0	0	0	1	7	2	3	P
Elmidae	470	31	204	9	314	165	101	96	CG/Sc/Sh
Gyrinidae	17	3	3	2	24	10	15	1	P
Psephenidae	162	12	91	0	32	11	4	1	Sc
Hydraenidae	1	0	2	0	0	0	0	0	P
Athericidae	30	6	11	6	0	5	0	0	P
Chironomidae	282	46	68	2	59	58	836	171	CG
Muscidae	7	0	0	0	6	21	86	105	P
Simuliidae	273	11	12	10	102	284	661	315	CF
Tipulidae	2	0	0	0	2	7	0	0	Sh
Tabanidae	215	39	51	12	172	42	9	68	P
Lymnaeidae	2	0	4	1	0	1	1	7	Sc
Physidae	0	0	0	0	0	6	142	82	Sc
Planorbidae	0	0	3	2	0	1	0	32	Sc
Thiaridae	0	1	2	1	0	0	0	1	Sc
Corbiculidae	58	11	10	1	280	25	2	9	CF
Total individuals	4815	625	1623	352	2284	2411	3788	2896	
Total family	30	22	26	23	29	31	27	31	

*Collector-gatherers CG, Collector-filterers CF, Shredder Sh, Scrapers Sc and Predators P.

Table 5. Abundance of functional feeding groups of the various sites in Dwars and Spekboom rivers.

Site	DS1	DS2	DS3	DS4	SS1	SS2	SS3	SS4
CF	1792	141	295	43	748	511	1146	700
CG	1280	330	798	205	791	1181	1344	1479
P	1078	97	213	86	288	273	1027	490
Sc	182	26	113	9	135	267	170	131
Sh	483	31	204	9	322	179	101	96
Total	4815	625	1623	352	2284	2411	3788	2896

abundance was found during winter, followed by summer, spring and then autumn. Collector-gatherers and collector-filterers were numerically dominant during all seasons (Figure 4).

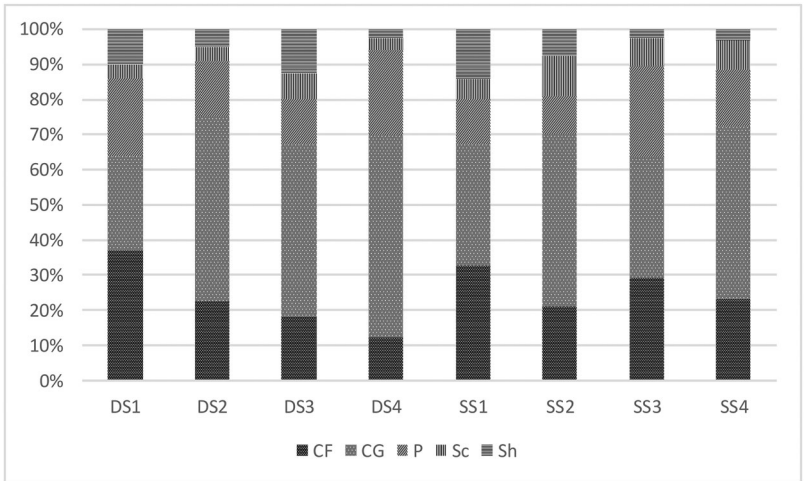


Figure 2. Composition of the FFGs of aquatic insects in the Dwars and Spekboom rivers.

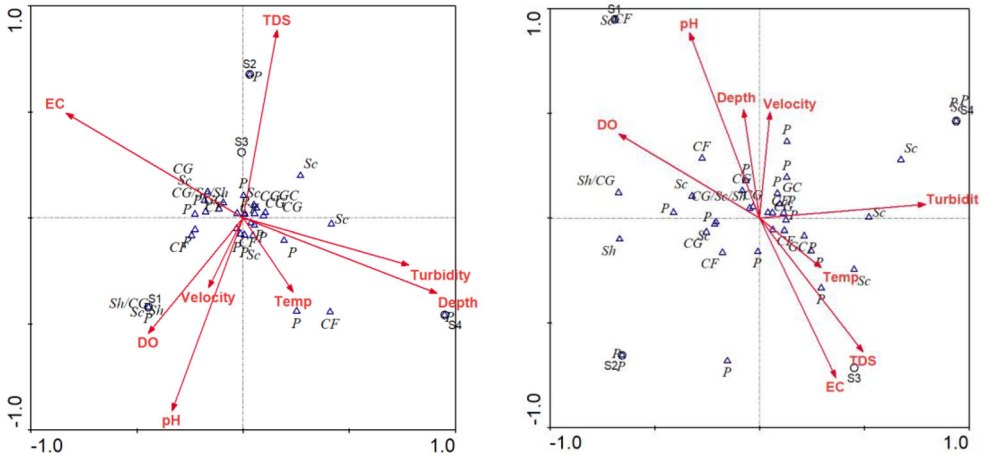


Figure 3. CCA plot depicting relationship between sampling sites (circles), FFG (triangles) and measured environmental variables (arrows). Axis 1 is horizontal and axis 2 vertical. (FFG: Collector-gatherers CG, Collector-filterers CF, Shredder Sh, Scrapers Sc and Predators P).

Table 6. The canonical correspondence analysis (CCA) between functional feeding groups and environmental variables for Dwars and Spekboom rivers.

Axes	Dwars River				Spekboom River			
	1	2	3	Total	1	2	3	Total
Eigenvalues	0.130	0.074	0.056	0.259	0.089	0.058	0.035	0.181
Taxa-environment correlations	0.99	0.99	0.99		0.99	0.99	0.99	
%variance explained of taxa data ^a	50.1	78.4	100.0		48.9	80.9	100.0	
%variance explained of taxa-environment relation ^a	50.1	78.4	100.0		48.9	80.9	100.0	
Sum of all eigenvalues				0.259				0.181

Discussion

The pattern of the physicochemical variables was more prominent between the rivers than among the sites. The high levels of EC at SS3 were due to discharge from the waste

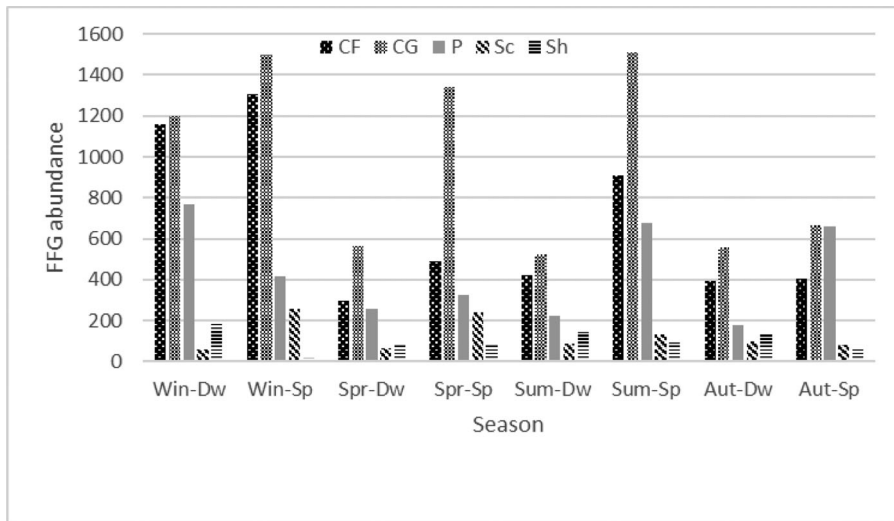


Figure 4. Seasonal distribution of macroinvertebrate FFGs at the sampling sites of the Dwars and Spekboom Rivers (Win = winter, Spr = spring, Sum = summer, Aut = autumn; Dw = Dwars River, Sp = Spekboom River).

water treatment plant close to the site (Kasangaki et al. 2008). The TDS levels recorded throughout the study were below the WHO (World Health Organization standard for Drinking Water) (2004) guideline of 1000 mg l^{-1} for the protection of aquatic life and for domestic water supply. The nutrient (NO_3 and PO_4) levels were very high at DS1, DS3 and SS3. The nitrate levels observed in the entire sampling sites were below the CCME (Canadian Council of Ministers of the Environment) (2003) value of 13 mg l^{-1} for the protection of aquatic life and US-EPA (United States Environmental Protection Agency) (2012) limit of 10 mg l^{-1} except at DS3. The high nitrate level at DS3 was attributed to leaching or runoff from agricultural land and the high phosphate level at SS3 was due to the discharge from the waste water treatment plant near the site. It has been reported that high concentrations of nutrients occur in waters that receive sewage, leaching or runoff from cultivated land.

The Spekboom River had a higher abundance and richness of macroinvertebrate taxa than the Dwars River. The taxa compositions across the sites were different for both rivers and the observed pattern was most likely due to different land cover characteristics (Cortes et al. 2011, 2013). The high abundance of macroinvertebrates at sites, DS1 and SS3 could be due to increased input of organic nutrients from agriculture and sewage plant, respectively. Though, SS3 showed the highest abundance of macroinvertebrates, it had the lowest taxa richness in the Spekboom River. Thus, the site might rather favoured some tolerant taxa due to the disturbance. This supports the fact that macroinvertebrate communities at degraded sites are characterized by either absence or presence of a few sensitive taxa and a greater dominance of only a few tolerant taxa (Elias et al. 2014).

The lowest values for Shannon's diversity index were obtained at downstream sites of the two rivers. This is partly due to discharges from agricultural and mining activities from upstream to downstream, which increased the concentration of suspended solids in the water affecting the presence of the macroinvertebrates (Bilotta and Brazier 2008). The EPT index followed similar trend as the diversity index, with higher EPT Index upstream than downstream of both rivers. Thus, the EPT index decreases with increasing human impacts and therefore an indication of water deterioration. The EPT index is widely used to assess human impacts in aquatic ecosystems (Moya et al. 2007, Couceiro et al. 2012).

The numbers of shredders and scrapers were very low and decreased at the downstream sites except at DS3, where there was an increase of scrapers and SS1 where there was a decrease in the abundance of shredders. Most of the shredders were recorded at upstream sites of both rivers and could be attributed to the occurrence of highest leaf fall in both rivers. Generally, the low numbers of shredders were partly due to less/loss of riparian vegetation resulting from human activities. Loss of riparian vegetation can cause loss of diversity and changes to structural and functional organization of macroinvertebrates in streams (Allan 2004, Jinggut et al. 2012). Furthermore, the low numbers of shredders could be due to the fact that tropical African rivers are different in their functioning to those located in temperate areas, as effective microbial activities replace shredder activity at high temperatures (Deemool and Prommi 2015). The highest numbers of scrapers were at sites DS1 and SS2 of the Dwars and Spekboom rivers respectively and could be due to an increase in algal production (periphyton) (Grubaugh et al. 1996).

The collector-gatherers were dominant in both rivers especially at DS1, SS3 and SS4. The collector-filterers were also well represented in both rivers and could be due to the fact that they can feed on a broader range of food materials than specialists groups (Merritt et al. 2002). The dominance of collectors across all sites in both rivers has also been reported in some tropical and subtropical rivers (Mishra and Nautiyal 2013). The shredders are usually replaced by microbial decomposition in tropical and subtropical rivers, which tends to be higher and occurs at a fast rate because of the higher water temperatures (Hyslop and Hunte-Brown 2012). The high taxa richness of predators along the whole longitudinal gradients of the two rivers may be due to availability of food and less competition. Predators are more abundant in small intermittent streams where fishes are absent (Rieradevall et al. 1999).

Canonical Correspondence analysis is a multivariate method to calculate the relationships between biological assemblages of taxa and the environment (Ter and Verdonschot 1995). Eigenvalues close to 1 represents a high degree of correspondence between taxa and sites, and an eigenvalue close to zero will indicate very little correspondence. In general, comparisons of benthic macroinvertebrate communities among the two rivers based on CCA analysis suggest that there is a relationship between the physicochemical variables and macroinvertebrate taxa.

The variation of the different FFG at different sampling sites can be explained by the availability of their food resources and the environmental variability at these sites. Studies have shown that macroinvertebrate fauna can be altered by land use practices (Miserendino and Masi 2010, Egler et al. 2012, Fierro et al. 2015). According to Barbour et al. (1996) specialized feeders, such as shredders and scrapers, are presumed to be more sensitive to perturbation, while generalists, such as collector-gatherers and collector-filterers, are more tolerant to pollution that might alter the availability of certain food. The dominance of collectors along entire river has also been reported in Kenyan highland streams (Masese et al. 2014).

Temporal differences in taxon richness and FFG abundance were recorded in both rivers. Generally, seasonal differences of macroinvertebrate distribution can be attributed to the dilution effect of increased flows during the rainy season (occurs between October and March). Highest taxon richness was recorded during the dry period (winter) in both rivers than from the onset of the rains (spring) and a significant reduction in abundance was recorded during autumn. The temporal and spatial variations in taxon richness, FFG composition and abundance of macroinvertebrates are attributed to variations in the study areas.

Conclusions

In both rivers, collector-gatherer dominated all the sites, except DS1 which was dominated by collector-filterers. The shredder and collector co-dominance in the headwaters was not observed in both rivers as predicted by RCC. Though the highest abundance of shredders was in the upstream of both rivers and the collector-gatherers dominated the downstream of the rivers, which supports the prediction of the RCC. The RCC predicts that shredders will decrease in abundance from headwaters to the mouth and that collector-gatherers, collector-filterers and scrapers will increase downstream, but in this study, the relatively high abundance of collector-gatherers and collector-filterers were found at all the sites. Thus, the distribution of the functional groups in the two rivers did not however conform fully to RCC pattern and it could be due to the degradation occurring in the area. The diversity index (H'), EFT and FFG reflect an impact of the anthropogenic activity on the rivers. The FFG pattern of the two rivers shows the influence of changing environmental conditions on macroinvertebrates along the rivers and therefore confirm that FFG is an effective tool to assess ecological integrity of rivers. The results suggest that policies governing changes in land use in the Steelpoort sub-catchment should take into consideration the impact of land use changes on the river systems.

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Data availability statement

Data used in this study are available upon request to the corresponding author.

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