Int. J. Aquat. Biol. (2019) 7(2): 71-84
ISSN: 2322-5270; P-ISSN: 2383-0956
Journal homepage: www.ij-aquaticbiology.com

Original Article

Identification of characteristic zooplankton species in the Kinyankonge River basin, Burundi

Simon Buhungu[*1,2], Marcel Donou[3], Gaspard Ntakimazi[1], Clément Agossou Bonou[4], Elie Montchowui[2]

[1]Centre de Recherche en Sciences Naturelles et de l'Environnement, Université du Burundi, BP 2700 Bujumbura, Burundi.
[2]Laboratoire de Recherche en Aquaculture et en Biologie et Ecologie Aquatiques, Ecole d'Aquaculture, Université Nationale d'Agriculture, Benin.
[3]Laboratoire de Biomathématique et d'Estimation Forestière, Université d'Abomey Calavi, Benin.
[4]Laboratoire de Recherche en Biologie Appliquée, Ecole Polytechnique d'Abomey-Calavi, Université d'Abomey-Calavi, BP 2009 Cotonou, Benin.

Abstract: The objective of this study is to determine the zooplankton species that characterize the Kinyankonge River basin in Burundi. Thus, zooplankton was sampled monthly over a period of 18 months (from July 2015 to June 2016, then from January 2017 to June 2017) at seven stations. The Indicator Value (IndVal) of the identified zooplankton species and the coverage of stations were determined. The results showed that three species characterized significantly the most upstream station whereas the water of the irrigation channel was characterized by 4 species. The waters of the Nyabagere tributary and the wastewater treatment plant are characterized by 1 and 5 species, respectively. Furthermore, the dry season was characterized by 4 singletons and 13 pairs of species, while the rainy season was characterized by 11 pairs of species. Moreover, the group of upstream stations was characterized by 5 species while 3 species characterized the group of downstream stations. These species highlighted by the indicator value method can be used to characterize stations in the Kinyankonge River and provide information on seasonal changes.

Article history:
Received 28 August 2018
Accepted 4 January 2019
Available online 25 April 2019

Keywords:
Zooplankton
Characteristic species
Indicator value
Kinyankonge

Introduction

Zooplankton plays an important role in aquatic ecosystems (Baloch et al., 2005). It is considered as one of the most important food sources to the aquatic organisms particularly to planktivorous. Zooplankton community constitutes a way of energy flux transfer through aquatic food webs especially between phytoplankton and the high levels (Santos-Wisniewski et al., 2006). Zooplankton species are used as bioindicators of the quality of water in lakes and rivers (El-Bassat and Taylor, 2007; Ahangar et al., 2012), because of their sensitivity to changes in the ecological and environmental conditions of their habitats (Hanazato, 2001; Carignan and Villard, 2002; Niemi and McDonald, 2004; Brito et al., 2011; Güher et al., 2011; Primo et al., 2015). Their identification as characteristic species is a classical method often used in ecology (Legendre and Legendre, 2012). In fact, they early react to a large number of environmental changes. Such species or groups of species are called bioindicators (Parmesan, 2006; Jakhar, 2013; Primo et al., 2015) and are useful in predicting of the level or degree of pollution before the pollutants cause significant damage (Pai, 2002; Verma, 2002). Their identification can provide an indication of ecosystem health. They can thus act as an early warning system allowing the implementation of intensive conservation strategy to anticipate ecologic catastrophe (Chapin, 2000).

In ecology, environmental bioindicators are identified by establishing a strong relationship with some environmental characteristics (Kitching et al., 2000; Davis, 2001). They are now one of tools used by water quality monitoring programs worldwide (Furse et al., 2006; Marchant et al., 2006; Yagow et al., 2006; Borja et al., 2008). Especially, studies on the structure of zooplankton populations can be a tool for analyzing the environmental disturbances to which these organisms are subjected in aquatic environments (Sampaio et al., 2002; Eskinazi-Santanna et al., 2013). Therefore, through their indicator value of their community, the characteristic species can provide an

[*]Correspondence: Simon Buhungu
E-mail: buhusimon@gmail.com

DOI: https://doi.org/10.22034/ijab.v7i2.484

ecological significance to a classification of inspected stations and also highlight the functional characteristics of the studied system (Touzin, 2008).

Studies conducted on the Kinyankonge River have shown organic pollution coming from domestic discharges (Buhungu et al., 2017, 2018) and a zooplankton community included rotifers, copepods and cladoceran species (Buhungu et al., 2018). The current study aims to identify, using the method of Indicator Species Analysis, the spatial and seasonal characteristic species of this river basin, based on a determination of their indicator values

Materials and Methods

Study area and sampling stations: The Kinyankonge River is approximately 6.5 km long. It crosses a nearly slightly populated locality and is characterized by arable land stretches. The soil is marshy and is therefore favorable mainly for rice and fodder cultivation. To conduct this study, seven sampling stations have been selected based on the types of discharges and activities occurring around the river (Fig. 1). The first station S1 (3°20'22.765"S, 29°21'10.655"E, 774.5 m of altitude) is located upstream of the Kinyankonge River. It has been chosen in the Cibitoke district to investigate the river source which receives both wastewater and garbage. The second station S2 (3°20'30.527"S, 29°21'27. 655"E, 774.7 m of altitude) was chosen into the Gikoma Channel to assess the polluting load thrown out in Kinyankonge River. The third station S3 (3°20' 43.598"S, 29°21'27.468"E, 774.8 m of altitude) is located on the Nyabagere River, a tributary of the studied river. In fact, sand is extracted from Nyabagere River for the construction of a new neighborhood located on its shores. Sand removal operations cause a significant degradation of the substrate which is important for the aquatic organisms. On this station, the collected samples have also enabled the evaluation of the pollutants load discharged into the Kinyankonge River. The fourth station S4 (3°20´42.623"S, 29°21´11.275"E, 771.3 m of altitude) is located on the Kinyankonge River, downstream of the mouths of the Nyabagere tributary

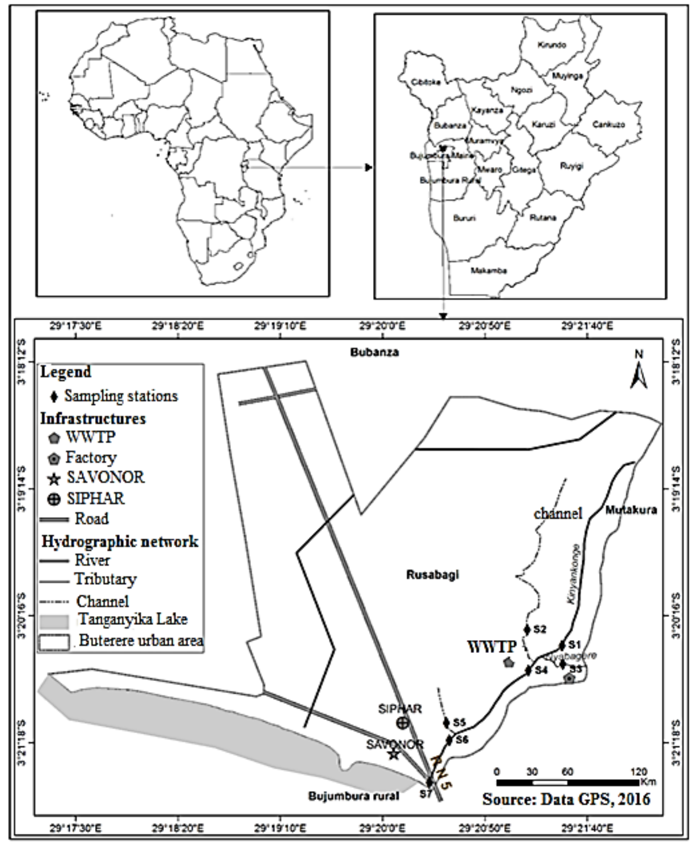

Figure 1. Geographic situation of sampling stations on Kinyankonge River.

and the Gikoma Canal. The fifth station S5 (3°21´15.908"S, 29°20´33.745"E, 765.6 m of altitude) is into the discharge channel of the wastewater treatment plant (WWTP) of Buterere discharging their effluents into the Kinyankonge River. The sixth station S6 (3°21´16.657"S, 29°20´32.535"E, 764.5 m of altitude) is positioned after the discharge point of the treatment plant. It receives the waters coming from the blending of WWTP effluents with the Kinyankonge river water. As for the seventh station S7 (3°21'37,346"S, 29°20'22,794"E, 760.5 m of altitude), it is located near the mouth of the Kinyankonge River and Tanganyika Lake. At this station, the river receives effluents from SAVONOR soap factory that are discharged after a physical pretreatment.

Sampling: Zooplankton samples were collected monthly over an 18-month period (from July 2015 to June 2016, then from January 2017 to June 2017). They were taken at morning between 7 AM and 11

AM using a 50 µm-mesh plankton net. Samples were taken vertically and over the entire water column. At each station, three different points were sampled to constitute a composite sample. The concentrated zooplankton was then recovered in a jar and immediately fixed with 5% formalin.

Observation, identification, and enumeration of zooplankton: In the laboratory, each zooplankton sample was concentrated to a volume of 100 ml. Zooplankton species were identified by microscopic observation using N-120/ N-120A light microscope from Ht-0205 Hiprove. This species identification operation was based on the specific morphological characters observable using different determination keys (Dussart, 1967; Pourriot, 1968; Rey and Saint Jean, 1968, 1969; Dussart, 1982). Then, individuals of identified species were also enumerated using a Burker Turk enumeration cell. The enumeration effort was set at 400 individuals for each inventoried species. Thus, the count rate varied according to species abundance and reached 100% of sample for rare species. An extrapolation was then made on total volume of sample, on the one hand, and the volume of filtered water, on the other hand, to assess the densities per liter of river water. The density was calculated using the following relation:

$$D = \frac{1000 * (ni * \frac{100}{AR})}{V}$$

Where D is the density (expressed in individuals per liter); ni the number of individuals recorded for species i; AR sample analysis rate corresponding to ni; V volume of filtered river water (ml).

Data analysis: In order to identify characteristic species, the indicator value of species was calculated and the significance of this value was tested using the Monte Carlo permutation test. This test enables to verify whether the preference of a species for a type of habitat is significantly higher than it is suggested by a random distribution (Dufrêne and Legendre, 1997). The indicator value of species that measures its predictive value as indicator of the conditions prevailing in a station or a season (De Cáceres and Legendre, 2009) is given by the following relation according to Dufrêne and Legendre (1997):

$$\text{IndVal}ij = \text{A}ij \times \text{B}ij \times 100$$

In this relation, A*ij* = N individuals *ij* / N individuals *i*, and represents the specificity, while B*ij* = N sites *ij* / N sites *j*, and corresponds to the fidelity. The indicspecies package of R (R Core Team, 2015) was used for testing singletons and species pairs, which provide better information on habitat ecology. In this study, analyses were limited to singletons and species pairs to limit the complexity of characteristic species identification. This option was done in order to avoid very large numbers of possibilities that could reduce the reliability of the analysis and making them too long (De Cáceres and Legendre, 2009).

The coverage of stations, groups of stations and seasons was evaluated by the "strassoc", "coverage" and "plotcoverage" functions that were used for the calculation and graphical representation of the coverage according to the specificity (A) values. For this analysis, only species with fidelity values B > 0.1 were included for eliminating low fidelity species. A comparison was made between singleton coverage and species pairs. All the analyses were performed with the indicspecies package (De Caceres and Legendre, 2009) of the R software (R Core Team, 2015).

Results

Characteristic species of stations, group of stations and seasons: A total of 36 zooplankton species inventoried in the Kinyankonge River Basin (Buhungu et al., 2018) were used for the identification of characteristic species. Singletons and species pairs considered as characteristics of stations (Table 1), groups of stations (Table 2) and seasons (Table 3) were the significant ones at 5% threshold with indicator value IndVal ≥ 0.50. Thus, no species or pair of species characterized stations S6 and S7. The first station (S1) was characterized by 8 pairs of species and 3 singletons (*Lecane luna*, *L. bulla* and *Alonella* sp.), the second station (S2) by 70 pairs of species and 4 singletons (*Polyarthra vulgaris*, *Brachionus quadridentatus, B. patulus* and *Philodina* sp.), the third station (S3) by one singleton (*Keratella tecta),* the fourth station (S4) by 2 pairs of species and the fifth

Table 1. Indicator values (IndVal) of characteristic species of the stations.

Stations		**Species**	**A**	**B**	**IndVal**	**P-value**	**Sig.**
Station S1	Singletons	Leca_lu	0.43	0.94	0.64	0.019	*
		Leca_bul	0.30	1.00	0.55	0.040	*
		Alon_sp(¥)	0.59	0.44	0.51	0.002	**
	Pairs	Alon_sp+Rota_sp(¥)	0.67	0.44	0.55	0.001	***
		Leca_lu+Rota_sp(¥)	0.34	0.83	0.53	0.008	**
		Leca_bul+Leca_lu(¥)	0.30	0.94	0.53	0.005	**
		Leca_lu+Naup(¥)	0.31	0.89	0.53	0.004	**
		Alonsp+Brach pat(¥)	0.61	0.44	0.52	0.002	**
		Alon_sp+Leca_bul(¥)	0.59	0.44	0.51	0.002	**
		Alon_sp+Leca_lu(¥)	0.59	0.44	0.51	0.002	**
		Alon_sp+Naup(¥)	0.59	0.44	0.51	0.002	**
		Alon_sp+Brach_caly	0.52	0.44	0.48	0.002	**
		Alon_sp+Lepa_pat	0.83	0.28	0.48	0.002	**
		Anur_fis+Poly_vul	0.59	0.39	0.48	0.007	**
		Leca_bul+Lepa_pat	0.37	0.61	0.47	0.069	ns
		Alon_sp+Brach_quad	0.67	0.33	0.47	0.003	**
		Alon_sp+Brach_ang	0.57	0.39	0.47	0.002	**
		Alon_sp+Poly_sp	0.97	0.22	0.47	0.003	**
		Brach_bid+Leca_lu	0.27	0.78	0.46	0.038	*
		Brach_ang+Leca_lu	0.25	0.83	0.46	0.040	*
		Alon_sp+Moin_sp	0.46	0.44	0.45	0.001	***
		Anur_fis+Leca_lu	0.44	0.44	0.44	0.025	*
		Alon_sp+Brach_bid	0.69	0.28	0.44	0.004	**
		Cepha_gib+Lepa_pat	0.38	0.50	0.44	0.141	ns
		Alon_sp+Poly_vul	0.54	0.33	0.42	0.006	**
		Alon_sp+Fili_ter	0.51	0.33	0.41	0.013	*
		Cepha_gib+Leca_bul	0.33	0.50	0.41	0.289	ns
		Anur_fis+Rota_sp	0.49	0.33	0.40	0.035	*
		Alon_sp+Aspl_sp	0.97	0.17	0.40	0.014	*
		Alon_sp+Aspl_pri	0.46	0.33	0.39	0.014	*
		Anur_fis+Brach_pat	0.39	0.39	0.39	0.037	*
		Anur_fis+Brachquad	0.45	0.33	0.39	0.026	*
		Anur_fis+Leca_bul	0.33	0.44	0.39	0.115	ns
		Alon_sp+Plat_quad	0.52	0.28	0.38	0.032	*
		Alon_sp+Micro_sp	0.61	0.22	0.37	0.019	*
Station S2	Singletons	Poly_vul	0.80	0.88	0.84	0.003	**
		Brach_quad	0.90	0.75	0.82	0.006	***
		Brach_pat	0.59	1.00	0.77	0.001	***
		Phil_sp	0.42	0.81	0.58	0.010	**
		Rota_sp	0.35	0.94	0.58	0.065	ns
		Aspl_sp	0.74	0.44	0.57	0.069	ns
		Brach_bid	0.44	0.63	0.52	0.156	ns
		Kera_trop	0.51	0.44	0.47	0.011	*
		Moin_sp	0.31	0.69	0.46	0.367	ns
	Pairs	Brachquad+Poly vul(¥)	0.91	0.75	0.83	0.001	***
		Brach_quad+Naup(¥)	0.84	0.75	0.79	0.003	**
		Brachquad+Rota sp(¥)	0.83	0.75	0.79	0.002	**
		Brach_pat+Naup(¥)	0.60	1.00	0.77	0.001	***
		Poly_vul+Rota_sp(¥)	0.66	0.88	0.76	0.001	***
		Brach_pat+Leca_bul	0.57	1.00	0.76	0.001	***
		Naup+Poly_vul	0.65	0.88	0.76	0.002	**
		Brach_quad+Phil_sp	0.77	0.69	0.73	0.001	***

Table 1. Continued.

Stations		Species	A	B	IndVal	P-value	Sig.
		Phil_sp+Poly_vul	0.65	0.81	0.73	0.001	***
		Brach_pat+Poly_vul	0.60	0.88	0.73	0.001	***
		Fili_ter+Phil_sp	0.64	0.81	0.72	0.001	***
		Naup+Rota_sp	0.56	0.94	0.72	0.002	**
		Brach_pat+Fili_ter	0.59	0.88	0.72	0.001	***
		Brach_pat+Phil_sp	0.59	0.81	0.70	0.001	***
		Brach_pat+Rota_sp	0.52	0.94	0.70	0.001	***
		Brach_bid+Brach_pat	0.75	0.63	0.69	0.001	***
		Brach_pat+Brach quad	0.62	0.75	0.68	0.001	***
		Naup+Phil_sp	0.56	0.81	0.68	0.001	***
		Brach_quad+Fili_ter	0.60	0.75	0.67	0.004	**
		Aspl_pri+Brach_pat	0.53	0.81	0.66	0.001	***
		Phil_sp+Rota_sp	0.52	0.81	0.65	0.002	**
		Fili_ter+Poly_vul	0.47	0.88	0.64	0.001	***
		Brach_pat+Leca_lu	0.43	0.94	0.64	0.001	***
		Fili_ter+Rota_sp	0.45	0.88	0.63	0.001	***
		Aspl_sp+Brach_quad	0.89	0.44	0.62	0.006	**
		Aspl_pri+Brach_quad	0.56	0.69	0.62	0.003	**
		Brach_ang+Brach pat	0.44	0.88	0.62	0.001	***
		Aspl_sp+Poly_vul	0.87	0.44	0.62	0.022	*
		Brach_quad+Lecabul	0.49	0.75	0.61	0.003	**
		Leca_lu+Moin_sp	0.52	0.69	0.60	0.001	***
		Brach_pat+Moin_sp	0.52	0.69	0.60	0.001	***
		Aspl_sp+Naup	0.80	0.44	0.59	0.055	ns
		Brach_bid+Phil_sp	0.70	0.50	0.59	0.005	**
		Aspl_sp+Rota_sp	0.79	0.44	0.59	0.044	*
Station S2	Pairs	Brach_ang+Brach_qud	0.50	0.69	0.59	0.001	***
		Aspl_pri+Poly_vul	0.42	0.81	0.59	0.001	***
		Aspl_pri+Fili_ter	0.42	0.81	0.59	0.001	***
		Moin_sp+Phil_sp	0.61	0.56	0.59	0.001	***
		Leca_bul+Poly_vul	0.39	0.88	0.59	0.001	***
		Moin_sp+Poly_vul	0.54	0.63	0.58	0.002	**
		Fili_ter+Leca_bul	0.38	0.88	0.58	0.001	***
		Brach_quad+Lepapat	0.60	0.56	0.58	0.001	***
		Leca_bul+Moin_sp	0.48	0.69	0.58	0.001	***
		Brach_pat+Lepa_pat	0.53	0.63	0.57	0.002	**
		Brach_bid+Naup	0.52	0.63	0.57	0.023	*
		Brach_pat+Cephagib	0.58	0.56	0.57	0.001	***
		Brach_quad+Leca_lu	0.43	0.75	0.57	0.001	***
		Aspl_sp+Phil_sp	0.74	0.44	0.57	0.014	*
		Fili_ter+Leca_lu	0.37	0.88	0.57	0.001	***
		Brach_bid+Rota_sp	0.56	0.56	0.56	0.015	*
		Leca_lu+Phil_sp	0.37	0.81	0.55	0.003	**
		Aspl_pri+Rota_sp	0.37	0.81	0.55	0.002	**
		Cepha_gib+Moin_sp	0.59	0.50	0.54	0.006	**
		Moin_sp+Rota_sp	0.43	0.69	0.54	0.003	**
		Aspl_sp+Brach_pat	0.67	0.44	0.54	0.008	**
		Leca_bul+Phil_sp	0.36	0.81	0.54	0.003	**
		Aspl_pri+Moin_sp	0.47	0.63	0.54	0.001	***
		Leca_lu+Poly_vul	0.33	0.88	0.54	0.001	***
		Lepa_pat+Phil_sp	0.51	0.56	0.54	0.010	**
		Brach_caly+Brachpat	0.33	0.88	0.53	0.002	**
		Leca_bul+Rota_sp	0.29	0.94	0.53	0.003	**

Table 1. Continued.

Stations		Species	A	B	IndVal	P-value	Sig.
		Aspl_pri+Phil_sp	0.37	0.75	0.52	0.016	*
		Leca_bul+Naup	0.27	1.00	0.52	0.005	**
		Brach_bid+Leca_bul	0.43	0.63	0.52	0.024	*
		Brach_bid+Fili_ter	0.48	0.56	0.52	0.053	ns
		Brach_quad+Keratro	0.71	0.38	0.52	0.001	***
		Brach_quad+Moinsp	0.47	0.56	0.51	0.001	***
		Aspl_pri+Leca_lu	0.32	0.81	0.51	0.004	**
		Aspl_sp+Lepa_pat	0.58	0.44	0.51	0.014	*
		Brach_pat+Kera_trop	0.58	0.44	0.50	0.003	**
		Brach_pat+Micro_sp	0.57	0.44	0.50	0.013	*
		Aspl_pri+Lepa_pat	0.50	0.50	0.50	0.028	*
		Brach_bid+Kera_trop	0.77	0.31	0.49	0.003	**
		Cepha_gib+Phil_sp	0.48	0.50	0.49	0.024	*
		Aspl_pri+Leca_bul	0.29	0.81	0.49	0.028	*
		Brach_caly+Leca_lu	0.27	0.88	0.49	0.010	**
		Kera_trop+Naup	0.54	0.44	0.49	0.007	**
		Brach_ang+Brachbid	0.41	0.56	0.48	0.037	*
		Brach_quad+Cephagi	0.46	0.50	0.48	0.039	*
		Aspl_sp+Fili_ter	0.53	0.44	0.48	0.044	*
		Kera_trop+Rota_sp	0.52	0.44	0.48	0.006	**
		Fili_ter+Kera_trop	0.52	0.44	0.48	0.006	**
		Brach_pat+Trop_sp	0.33	0.69	0.48	0.007	**
Station S2	Pairs	Aspl_sp+Aspl_pri	0.59	0.38	0.47	0.024	*
		Fili_ter+Lepa_pat	0.39	0.56	0.47	0.038	*
		Brach_ang+Poly_vul	0.27	0.81	0.47	0.040	*
		Brach_quad+Plat_qua	0.43	0.50	0.46	0.007	**
		Brach_ang+Keratrop	0.49	0.44	0.46	0.013	*
		Kera_trop+Trop_sp	0.48	0.44	0.46	0.007	**
		Kera_trop+Leca_lu	0.48	0.44	0.46	0.009	**
		Leca_lu+Micro_sp	0.47	0.44	0.45	0.020	*
		Kera_trop+Poly_vul	0.46	0.44	0.45	0.010	**
		Poly_vul+Trop_sp	0.30	0.63	0.43	0.046	*
		Leca_lu+Trop_sp	0.30	0.63	0.43	0.080	ns
		Brach_quad+Trop_sp	0.37	0.50	0.43	0.015	*
		Kera_trop+Leca_bul	0.42	0.44	0.43	0.020	*
		Brach_caly+Lepapat	0.31	0.56	0.41	0.063	ns
		Moin_sp+Plat_quad	0.39	0.44	0.41	0.024	*
		Aspl_pri+Kera_trop	0.39	0.44	0.41	0.024	*
		Brach_bid+Moin_sp	0.45	0.38	0.41	0.018	*
		Lepa_pat+Plat_quad	0.38	0.44	0.41	0.024	*
		Aspl_sp+Leca_lu	0.38	0.44	0.41	0.041	*
		Brach_pat+Méso_sp	0.88	0.19	0.41	0.048	*
		Kera_trop+Moin_sp	0.61	0.25	0.39	0.015	*
		Phil_sp+Trop_sp	0.27	0.56	0.39	0.289	ns
		Brach_pli+Poly_sp	0.80	0.19	0.39	0.045	*
		Kera_trop+Micro_sp	0.73	0.19	0.37	0.025	*
	Singletons	Kera_tec	0.84	0.44	0.61	0.001	***
		Kera_tec+Rota_sp(¥)	0.85	0.44	0.61	0.001	***
		Aspl_pri+Keratec(¥)	0.83	0.44	0.61	0.001	***
Station S3		Kera_tec+Leca bul(¥)	0.78	0.44	0.59	0.001	***
	Pairs	Kera_tec+Phil_sp(¥)	0.88	0.39	0.59	0.001	***
		Brachang+Keratec(¥)	0.78	0.39	0.55	0.001	***
		Cepha_gib+Kera_tec	0.77	0.28	0.46	0.008	**
		Kera_tec+Lepa_pat	0.76	0.28	0.46	0.005	**

Table 1. Continued.

Stations		Species	A	B	IndVal	P-value	Sig.
Station S4	Pairs	Brach_caly+Brach_qu	0.63	0.56	0.59	0.047	*
		Brach_caly+Poly_vul	0.40	0.83	0.58	0.021	*
		Aspl_sp+Brach_caly	0.53	0.39	0.46	0.122	ns
		Brach_caly+Cepha_gi	0.41	0.50	0.45	0.082	ns
		Cepha_gib+Fili_sp	0.63	0.22	0.38	0.038	*
		Brach_ang+Cephagib	0.31	0.44	0.37	0.350	ns
		Aspl_sp+Brach_fal	0.81	0.17	0.37	0.048	*
Station S5	Singletons	Brach_caly	0.76	0.94	0.85	0.001	***
		Brach_ang	0.64	1.00	0.80	0.001	***
		Fili_ter	0.53	0.83	0.66	0.003	**
		Micro_sp	0.96	0.44	0.65	0.026	*
		Naup	0.36	1.00	0.60	0.131	ns
		Fili_sp	0.51	0.50	0.51	0.015	*
		Trop_sp	0.33	0.72	0.49	0.029	*
		Méso_sp	0.80	0.28	0.47	0.025	*
	Pairs	Brachang+Brachca(¥)	0.75	0.94	0.84	0.001	***
		Brach_caly+Filiter(¥)	0.79	0.83	0.81	0.001	***
		Brach_caly+Naup(¥)	0.61	0.94	0.76	0.001	***
		Brach_ang+Filiter(¥)	0.65	0.83	0.74	0.002	**
		Brach_ang+Naup(¥)	0.48	1.00	0.69	0.001	***
		Micro_sp+Naup	0.86	0.44	0.62	0.012	*
		Brach_caly+Fili_sp	0.72	0.50	0.60	0.001	***
		Brach_caly+Micro sp	0.79	0.44	0.59	0.007	**
		Fili_sp+Naup	0.69	0.50	0.59	0.004	**
		Brach_ang+Micro_sp	0.74	0.44	0.57	0.009	**
		Fili_sp+Micro_sp	0.84	0.39	0.57	0.001	***
		Brach_ang+Fili_sp	0.61	0.50	0.55	0.002	**
		Fili_ter+Micro_sp	0.65	0.44	0.54	0.013	*
		Brach_caly+Trop_sp	0.42	0.67	0.53	0.004	**
		Fili_ter+Naup	0.33	0.83	0.52	0.065	,
		Brach_caly+Méso_sp	0.92	0.28	0.51	0.010	**
		Brach_ang+Méso_sp	0.88	0.28	0.50	0.007	**
		Naup+Trop_sp	0.33	0.72	0.49	0.020	*
		Brach_ang+Trop_sp	0.32	0.72	0.48	0.016	*
		Fili_ter+Méso_sp	0.82	0.28	0.48	0.011	*
		Aspl_pri+Brach_caly	0.30	0.72	0.46	0.145	ns
		Fili_sp+Trop_sp	0.58	0.33	0.44	0.004	**
		Micro_sp+Trop_sp	0.60	0.28	0.41	0.033	*
Station S6	Pairs	Poly_sp+Trop_sp	0.38	0.39	0.39	0.027	*
		Brach_fal+Fili_sal	1.00	0.11	0.33	0.157	ns
		Aspl_pri+Fili_sal	0.46	0.22	0.32	0.093	ns
		Fili_sal+Poly_vul	0.46	0.22	0.32	0.101	ns
Station S7	Pairs	Anur_fis+Phil_sp	0.27	0.33	0.30	0.350	ns
		Cepha_gib+Trop_sp	0.24	0.33	0.28	0.651	ns
		Fili_sp+Scar_lon	0.60	0.11	0.26	0.325	ns
		Plat_quad+Scar_lon	0.57	0.11	0.25	0.315	ns
		Anur_fis+Brach_fal	0.52	0.11	0.24	0.357	ns

A=specificity, B=fidelity, P-value=probability, Sig= significance level, code of significance: 0.001***; 0.01*; 0. 05*; ns: non significance, (¥): species more significantly characteristic of the station with highest indicator value.

station (S5) by 17 pairs of species and 5 singletons (*B. calyciflorus*, *B. angularis*, *Filina terminalis*, *Microcyclops* sp. and *Filina* sp.) (Table 1).

The group of upstream stations (S1, S2, S3 and S4) was characterized by 14 pairs of species and 5 singletons (*L. luna*, *L. bulla*, *P. vulgaris*, *B. quadridentatus* and *B. patulus*), while 8 pairs of species and 3 singletons (*B. angularis*, *B. calyciflorus* and *Tropocyclops* sp.) were characteristic of the group of downstream stations (S5, S6 and S7) (Table 2). The

Table 2. Species characteristic of groups of stations.

Group of stations		Species	A	B	stat	Pvalue	Sig.
Upstream stations	Singletons	Leca_bul	0.73	1.00	0.86	0.001	***
		Leca_lu	0.75	0.84	0.80	0.005	**
		Poly_vul (¥)	0.93	0.66	0.78	0.036	*
		Brach_quad	0.99	0.59	0.76	0.001	***
		Brach_pat	0.79	0.70	0.74	0.001	***
	Pairs	Leca_bul+Rota_sp (¥)	0.72	0.87	0.79	0.001	***
		Leca_bul+Leca_lu (¥)	0.74	0.84	0.79	0.001	***
		Leca_bul+Naup (¥)	0.72	0.86	0.78	0.002	**
		Rota_sp	0.62	0.87	0.74	0.174	ns
		Leca_lu+Naup (¥)	0.79	0.74	0.77	0.001	***
		Aspl_pri+Leca_bul	0.67	0.86	0.76	0.003	**
		Leca_lu+Rota_sp	0.77	0.74	0.76	0.001	***
		Brach_pat+Leca_bul	0.81	0.70	0.75	0.001	***
		Naup+Rota_sp	0.76	0.74	0.75	0.105	ns
		Brach_quad+Naup	0.98	0.57	0.75	0.001	***
		Aspl_pri+Leca_lu	0.77	0.73	0.75	0.001	***
		Brach_quad+Leca_bul	0.94	0.59	0.74	0.001	***
		Brach_pat+Naup	0.82	0.67	0.74	0.001	***
		Aspl_pri+Rota_sp	0.73	0.74	0.74	0.001	***
		Naup+Poly_vul	0.86	0.63	0.74	0.048	*
		Poly_vul+Rota_sp	0.85	0.63	0.73	0.019	*
Downstream stations	Singletons	Brach_ang	0.86	0.93	0.89	0.001	***
		Brach_caly	0.98	0.81	0.89	0.001	***
		Fili_ter	0.71	0.76	0.73	0.052	ns
		Naup	0.54	0.94	0.71	0.649	ns
		Trop_sp	0.65	0.74	0.70	0.013	*
	Pairs	Brachang+Brachcaly (¥)	0.95	0.80	0.87	0.001	***
		Brach_caly+Fili_ter (¥)	0.94	0.72	0.82	0.001	***
		Brach_caly+Naup (¥)	0.82	0.80	0.81	0.001	***
		Brach_ang+Fili_ter (¥)	0.88	0.74	0.81	0.001	***
		Brach_ang+Naup (¥)	0.69	0.91	0.79	0.001	***
		Brach_caly+Trop_sp	0.79	0.65	0.71	0.001	***
		Naup+Trop_sp	0.65	0.70	0.68	0.016	*
		Brach_ang+Trop_sp	0.65	0.70	0.68	0.019	*

A=specificity, B=fidelity, P-value=probability, Sig= significance level, code of significance: 0.001***; 0.01*; 0.05*

dry season was characterized by 13 pairs of species and 4 singletons (*L. bulla*, *Asplanchna priodonta*, *Brachionus bidentatus* and *Anuraeopsis fissa*) while the rainy season was characterized by 11 pairs (Table 3).

Spatial coverage of characteristic species: Station coverage by characteristic species is shown by Figure 2. For each station, coverage of singletons and this of species pairs were compared. The coverage varied from a station to another according to characteristic species recorded. Indeed, the coverage decreased as specificity increased for both singletons and pairs of characteristic species. Therefore, when the selection of characteristic species were made more rigorously, the coverage of a station by the singletons or by the pairs of characteristic species decreased. At station S1, the coverage was total at specificity threshold for A=0.45 for singletons as well as characteristic pairs. At a higher specificity, it noticed that characteristic species number was no more sufficient to cover the entire station. This remark is more pronounced when considering only singletons.

As for station S2, the coverage was total at up to A=0.6 for singletons and A=0.75 for species pairs. Station S3 was the least covered. In this station, the coverage was total only A=0.18 for both singletons and species pairs. For stations S4, S6 and S7, singleton coverage decreased before pair coverage. Stations S2 and S5 were covered by many species for both singletons and species pairs.

Table 3. Seasonal characteristic species.

Seasons		Species	A	B	stat	P-value	Sig.
Rainy	Singletons	Moin_sp	0.71	0.51	0.60	0.126	ns
	Pairs	Leca_bul+Rota_sp(¥)	0.63	0.90	0.76	0.008	**
		Brach_ang+Rota_sp	0.63	0.84	0.73	0.017	*
		Brach_caly+Leca_lu	0.65	0.66	0.65	0.043	*
		Brach_pat+Leca_lu	0.67	0.63	0.65	0.036	*
		Rota_sp+Trop_sp	0.69	0.58	0.64	0.03	*
		Fili_ter+Leca_bul	0.56	0.73	0.64	0.203	ns
		Aspl_pri+Rota_sp	0.52	0.74	0.62	0.371	ns
		Leca_bul+Moin_sp	0.78	0.48	0.61	0.028	*
		Leca_lu+Moin_sp	0.77	0.46	0.60	0.034	*
		Brach_caly+Brach_pat	0.62	0.57	0.60	0.078	ns
		Brach_pat+Moin_sp	0.83	0.42	0.59	0.012	*
		Brach_caly+Trop_sp	0.57	0.57	0.57	0.305	ns
		Brach_pat+Trop_sp	0.76	0.43	0.57	0.03	*
		Moin_sp+Phil_sp	0.86	0.37	0.57	0.029	*
		Brach_ang+Kera_trop	1.00	0.20	0.45	0.027	*
		Brach_caly+Kera_trop	1.00	0.20	0.45	0.019	*
		Kera_trop+Leca_bul	1.00	0.20	0.45	0.024	*
		Kera_trop+Leca_lu	1.00	0.20	0.45	0.02	*
		Plat_quad+Poly_vul	0.58	0.34	0.44	0.401	ns
		Fili_ter+Kera_trop	1.00	0.18	0.42	0.033	*
		Kera_trop+Naup	1.00	0.18	0.42	0.034	*
		Kera_trop+Rota_sp	1.00	0.18	0.42	0.032	*
		Kera_trop+Trop_sp	1.00	0.18	0.42	0.031	*
		Micro_sp+Trop_sp	1.00	0.18	0.42	0.024	*
Dry	Singletons	Brach_ang	0.79	0.85	0.82	0.152	ns
		Leca_bul	0.71	0.91	0.81	0.025	*
		Naup	0.71	0.91	0.80	0.14	ns
		Aspl_pri	0.69	0.91	0.79	0.005	**
		Brach_bid	0.91	0.67	0.78	0.001	***
		Anur_fis	0.84	0.52	0.66	0.001	***
		Poly_vul	0.90	0.42	0.62	0.983	ns
		Trop_sp	0.49	0.79	0.62	0.438	ns
		Hexa_sp	0.75	0.24	0.43	0.013	*
	Pairs	Aspl_pri+Naup(¥)	0.68	0.82	0.75	0.011	*
		Aspl_pri+Brach_bid(¥)	0.84	0.64	0.73	0.001	***
		Aspl_pri+Brach_ang(¥)	0.67	0.79	0.73	0.03	*
		Aspl_pri+Leca_bul(¥)	0.64	0.82	0.73	0.03	*
		Brach_bid+Naup(¥)	0.84	0.61	0.72	0.001	***
		Leca_bul+Naup	0.62	0.82	0.71	0.204	ns
		Brach_bid+Leca_bul	0.77	0.64	0.70	0.001	***
		Brach_ang+Naup	0.59	0.82	0.70	0.427	ns
		Anur_fis+Aspl_pri	0.85	0.52	0.66	0.001	***
		Brach_ang+Brach_bid	0.79	0.55	0.66	0.001	***
		Brach_ang+Brach_caly	0.83	0.52	0.65	0.776	ns
		Anur_fis+Leca_bul	0.84	0.48	0.64	0.001	***
		Leca_lu+Naup	0.58	0.70	0.64	0.415	ns
		Anur_fis+Brach_bid	0.86	0.45	0.63	0.001	***
		Anur_fis+Trop_sp	0.78	0.48	0.61	0.001	***
		Brach_ang+Leca_lu	0.52	0.70	0.60	0.622	ns
		Anur_fis+Naup	0.77	0.45	0.59	0.002	**
		Brach_caly+Naup	0.60	0.52	0.56	1	ns
		Anur_fis+Brach_ang	0.78	0.39	0.56	0.004	**
		Fili_ter+Hexa_sp	0.75	0.24	0.43	0.011	*

Table 3. Continued.

Seasons		Species	A	B	stat	P-value	Sig.
Dry	Pairs	Brach_ang+Hexa_sp	0.75	0.24	0.43	0.013	*
		Brach_caly+Hexa_sp	0.75	0.24	0.43	0.013	*
		Hexa_sp+Naup	0.75	0.24	0.43	0.013	*
		Fili_sp+Hexa_sp	0.85	0.21	0.42	0.005	**
		Brach_caly+Brach_quad	0.85	0.21	0.42	0.934	ns
		Brach_caly+Cepha_gib	0.66	0.27	0.42	0.953	ns
		Hexa_sp+Moin_sp	0.96	0.18	0.42	0.001	***
		Brach_ang+Brach_pli	0.82	0.21	0.42	0.026	*
		Hexa_sp+Leca_lu	0.96	0.18	0.42	0.007	**
		Hexa_sp+Poly_vul	0.95	0.18	0.42	0.006	**
		Hexa_sp+Leca_bul	0.93	0.18	0.41	0.012	*
		Aspl_sp+Naup	0.92	0.18	0.41	0.923	ns
		Hexa_sp+Rota_sp	0.91	0.18	0.41	0.012	*
		Cepha_gib+Hexa_sp	0.96	0.15	0.38	0.01	**
		Aspl_sp+Brach_caly	0.79	0.18	0.38	0.845	ns
		Hexa_sp+Trop_sp	0.92	0.15	0.37	0.006	**
		Aspl_pri+Micro_sp	0.80	0.15	0.35	0.74	ns
		Kera_qua	1.00	0.12	0.35	0.008	**
		Brach_bid+Kera_qua	1.00	0.12	0.35	0.008	**
		Kera_qua+Leca_bul	1.00	0.12	0.35	0.008	**
		Kera_qua+Naup	1.00	0.12	0.35	0.008	**
		Kera_qua+Trop_sp	1.00	0.12	0.35	0.008	**

A= specificity, B=fidelity, P-value=probability, Sig=level of significance, code of significance: 0.001***; 0.01*; 0.05*

Coverage of characteristic species according to station groups: The coverage of the group of upstream and downstream stations is shown in Figure 3. It remained maximal (100%) and decreased only beyond a specificity of 0.6 for both groups. In upstream group, this coverage is greater for pairs than for species singletons above 0.6. Downstream station group covers were almost identical for characteristic species pairs and singletons.

Coverage of characteristic species according to season: Seasonal coverage by characteristic species is presented in Figure 4. For each season, it compares singletons and pairs of characteristic species. In fact, the cover is much higher during the rainy season than the dry season; it remained maximal (100%) and decreases only beyond a specificity threshold of 0.8. On the other hand, in the dry season, it decreased starting with a specificity of 0.5. The coverage rate was almost identical for both characteristic species pairs and the singletons. However, the coverage seemed to decrease faster in dry season (starting with a specificity of 0.8) than in rainy season.

Discussions

This study on the identification of zooplankton species characteristic of the Kinyankonge River basin provides a diversity of knowledge on the spatial and seasonal distribution of these species. The use of the indicator value for zooplankton species in the Kinyankonge River basin has made it possible to develop a list of the most significant species for each station, group of stations and season. Singletons and/or pairs of characteristic species were found mostly at stations located in the upstream part of Kinyankonge River.

Thus, *L. luna*, *L. bulla,* and *Alonella* sp. were identified as characteristic of the first station (S1) which receives domestic discharges. Likewise, *P. vulgaris*, *B. quadridentatus*, *B. patulus* and *Philodina* sp. were identified as characteristic of the second station (S2) located into an irrigation channel receiving both agricultural and domestic discharges. Only *K. tecta* was characteristic of the third station (S3), enriched with suspended matter coming from sand operations. These aforementioned species

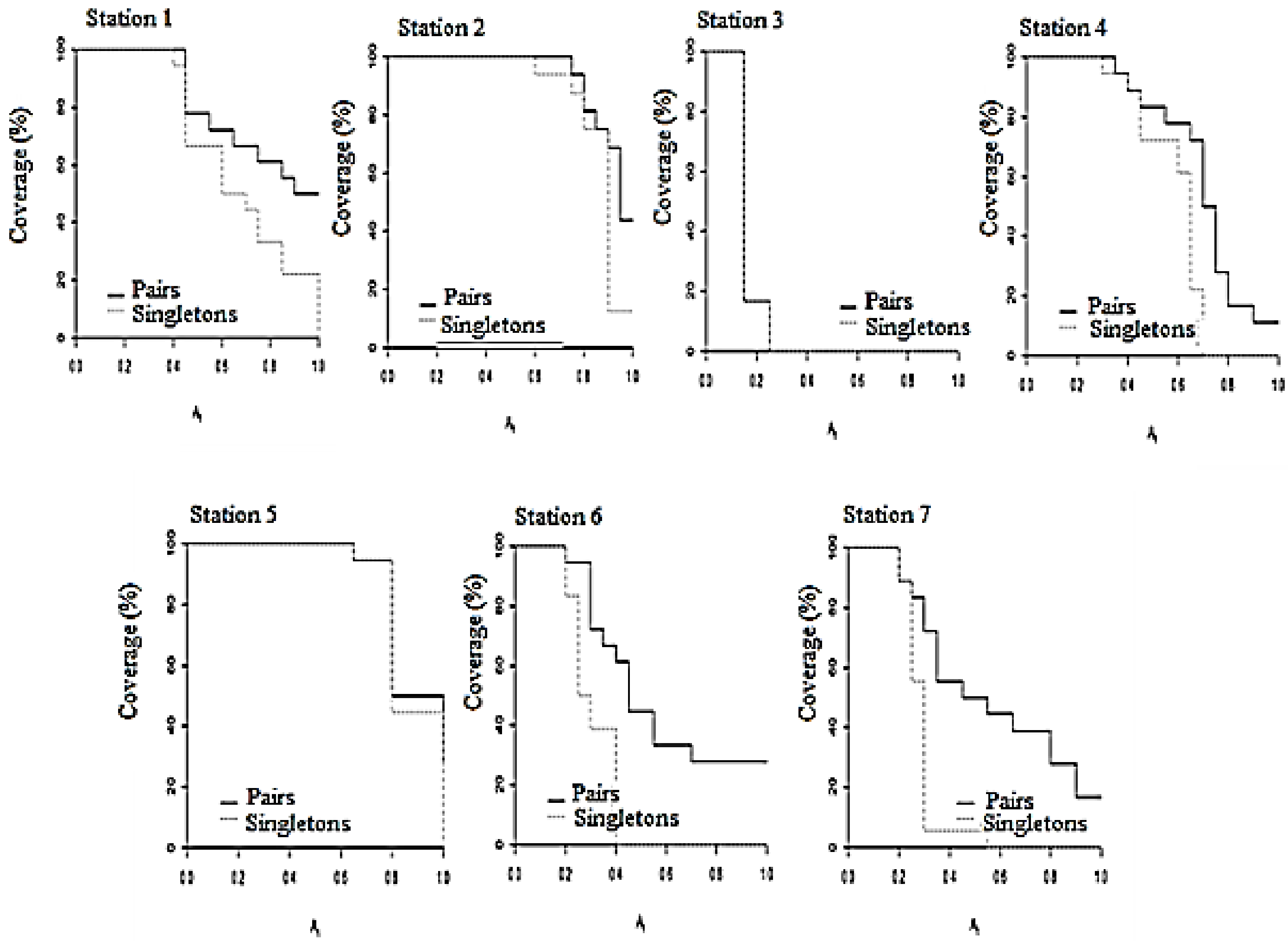

Figure 2. Coverage rates of characteristic species stations.

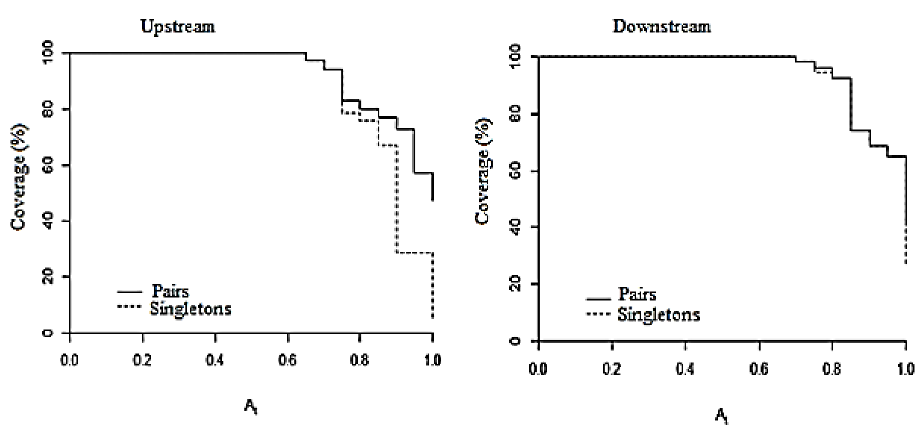

Figure 3. Coverage rates of characteristic species according to station groups.

establish themselves in waters characterized by high dissolved oxygen level and high transparency (Buhungu et al., 2018). For downstream stations, only station S5, which receives highly organic and mineralized effluents from wastewater treatment plant, was characterized by *B. calyciflorus*, *B. angularis*, *F. terminalis*, *Microcyclops* sp. and *Filina* sp. These species are characteristic of eutrophication environments (Baloch et al., 2005).

Furthermore, the combination of stations revealed

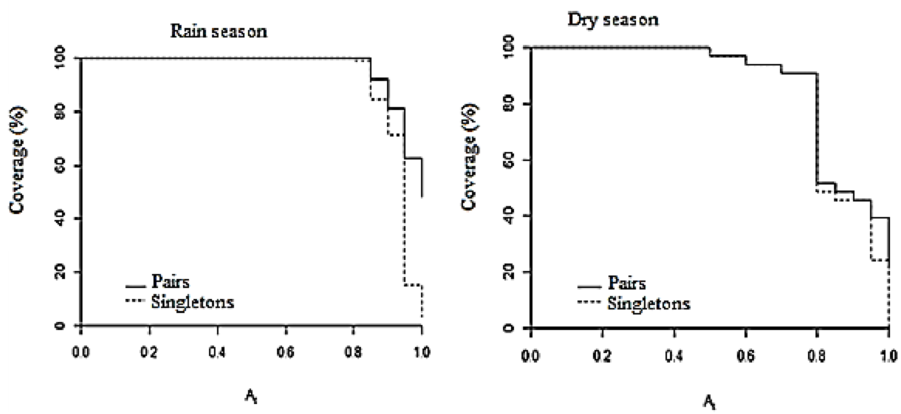

Figure 4. Seasonal coverage rates for characteristic species.

that 5 species (*L. luna*, *L. bulla*, *P. vulgaris*, *B. quadridentatus* and *B. patulus*) characterized the upstream stations, while 3 species (*B. calyciflorus*, *B. angularis* and *Tropocyclops* sp.) characterized downstream stations which waters were polluted by organic matter (Buhungu et al., 2017, 2018). In addition, the analysis of the indicator value for *B. calyciflorus* and *B. angularis* revealed that these species are pollutant-resistant. These results confirm those of Starling (2000) which showed that zooplankton species richness decreases with eutrophication degree in rivers and lakes. Similar results were found by Pedrozo and Rocha (2005) showing tolerance of *B. calyciflorus* and *B. angularis* to organic pollution and confirming several rotifers belonging to genera *Brachionus*, *Keratella* and *Fillina* are characteristic of organic-enriched environments (Isumbisho et al., 2006; Moshood, 2009; Ahmad et al., 2011).

It is important to notice that rotifers were the most abundant zooplankton species identified in this study, in both rainy and dry season, in upstream as well as downstream stations. They were distributed according to downstream-upstream gradient since much more characteristic species were recorded at upstream. This abundance of rotifers species can be justified by their opportunistic nature, giving them the ability to better withstand changes of environmental conditions and of the availability of food resources (Dumont, 1977; Matsumura-Tundisi et al., 1990; Zébazé et al., 2004; Bonecker et al., 2007).

Moreover, the river waters were characterized by singletons of rotifer species (*L. bulla*, *A. priodonta*, *B. bidentatus* and *A. fissa*) only during the dry season in which they were abundant. This may be due to the decreasing of water flow, creating thus favorable conditions for zooplankton egg-laying and hatching. In fact, in a river, the permanent renewal of the water does not favor the abundance of zooplankton (Ouattara et al., 2001). A strong water current enhance turbidity which, by decreasing light penetration into the water, reduces the production of phytoplankton organisms and, thereby, limits the development of their predators which are zooplanktonic organisms (Ouattara et al., 2001, 2007). On the other hand, season coverage seemed to decrease faster in the dry season than in the rainy season. This can be due to the fact that there are no other dry season characteristic species and the probability of finding it is low or even null (Walther and Moore, 2005).

Conclusion

This study highlighted zooplankton species that significantly characterized the sampling stations in the Kinyankonge River basin. The indicator species analysis method has identified the species that characterize each station, each group of stations, as well as seasons. It also pointed out the characteristic species favoured by dry season. Their absence in the mentioned season could be due to the environment disturbance by human activities. This study provides therefore important information for future researches about the specific composition of zooplankton at a given station and at a given time.

Acknowledgements

The authors thank the Government of Burundi for its scholarship and internship program which funded this research.

References

Ahangar I.A., Mir M.F., Saksena D.N., Ahangar M.A. (2012). Zooplankton diversity of Anchar Lake with relation to trophic status, Srinagar, Kashmir. Global Journal of Environmental Research, 6: 17-21.

Ahmad U., Parveen S., Khan A.A., Kabir H.A., Mola H.R.A., Ganai A.H. (2011). Zooplankton population in relation to physico-chemical factors of a sewage fed pond of Aligarh (UP), India. Biology and Medicine, 3(2): 336-341.

Baloch W.A., Jafri S.I.H., Soomro A.N. (2005). Spring zooplankton composition of Rawal Lake, Islamabad. Sindh University Research Journal, 37: 41-46.

Bonecker C.C., Nagae M.Y., Bletller M.C.M., Velho L.F.M., Lansac-Tôha F.A. (2007). Zooplankton biomass in tropical reservoirs in southern Brazil. Hydrobiologia, 579(1): 115-123.

Borja A., Bricker S.B., Dauer D.M., Demetriades N.T., Ferreira J.G., Forbes A.T., Hutchings P., Xiaoping J., Kenchington R., Marques J.C., Zhu C. (2008). Overview of integrative tools and methods in assessing ecological integrity in estuarine and coastal systems worldwide. Marine Pollution Bulletin, 56: 1519-1537.

Brito S.L., Maia-Barbosa P.M., Pinto-Coelho R.M. (2011). Zooplankton as an indicator of trophic conditions in two large reservoirs in Brazil: Zooplankton indicator of trophic conditions. Lakes and Reservoirs: Research and Management, 16(4): 253-264.

Buhungu S., Houssou A.M., Montchowui E., Ntakimazi G., Vasel J.L., Ndikumana T. (2017). Etablissement du pollutogramme et de l'hydrogramme de la rivière Kinyankonge, Burundi. International Journal of Biological and Chemical Sciences, 11(3): 1386-1399.

Buhungu S., Montchowui E., Barankanira E., Sibomana C., Ntakimazi G., Bonou C.A. (2018). Caractérisation spatio-temporelle de la qualité de l'eau de la rivière Kinyankonge, affluent du Lac Tanganyika, Burundi. International Journal of Biological and Chemical Sciences, 12(1): 576-595.

Carignan V., Villard M. (2002). Selecting indicator species to monitor ecological integrity: a review. Environmental Monitoring and Assessment, 78: 45-61.

Chapin F.S. (2000). Consequences of Changing Biodiversity. Nature, 405: 234-242.

Davis A.J. (2001). Dung beetles as indicators of change in the forests of northern Borneo. Journal of Applied Ecology, 38: 593-616.

De Caceres M., Legendre P. (2009). Associations between species and groups of sites: indices and statistical inference. Ecology, http://sites.google.com/site/ miqueldecaceres/. Accessed September 28th 2017.

Dufrêne M., Legendre P. (1997). Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs, 67: 345-366.

Dumont H.J. (1977). Biotic factors in population dynamics of rotifers. Archiv für Hydrobiologie–BeiheftErgebnisse, 8: 98-122.

Dussart B. (1967). Les copépodes des eaux continentales d'Europe occidentale II. Cyclopoïdes et Biologie. Boubée and Cie, Paris. 292 p.

Dussart B. (1982). Faune de Madagascar : Crustacés copépodes des eaux intérieures. ORSTOM-CNRS, Paris. 146 p.

El-Bassat R.A., Taylor W.D. (2007). The zooplankton community of Lake Abo Zaabal, a newly formed mining lake in Cairo. Egyptian African Journal of Aquatic Sciences, 32: 185-192.

Eskinazi-Santanna E.M., Menezes R., Costa I.S., Araújo M., Panosso R., Attayde J.L. (2013). Zooplankton assemblages in eutrophic reservoirs of the Brazilian semi-arid. Brazilian Journal of Biology, 73(1): 37-52.

Furse M.T., Hering D., Brabec K., Buffagni A., Sandin L., Verdonschot P.F.M. (2006). The ecological status of European rivers: evaluation and intercalibration of assessment methods. Hydrobiologia, 566: 1-2.

Güher H., Erdoğan S., Kırgız T., Çamur-Elipek B. (2011). The dynamics of zooplankton in national park of Lake Gala (Edirne-Turkey). Acta Zoologica Bulgarica, 63: 15-168.

Hanazato T. (2001). Pesticide effects on freshwater zooplankton: an ecological perspective. Environmental Pollution, 112(1): 1-10.

Isumbisho M., Sarmenton H., Kaningini B., Micha J.C., Descy J.P. (2006). Zooplankton of Lake Kivu, East Africa, half a century after the Tanganyika sardine introduction. Journal of Plankton Research, 28(11): 971-989.

Jakhar P. (2013). Role of phytoplankton and zooplankton as health indicators of aquatic ecosystem: A review. International Journal of Innovation Research Study, 2(12): 489-500.

Kitching R.L., Orr A.G., Thalib L., Mitchell H., Hopkins M.S., Graham A.W. (2000). Moth assemblages as indicators of environmental quality in remnants of upland Australian rain forest. Journal of Applied Ecology, 37: 284-297.

Legendre P., Legendre L. (2012). Numerical ecology, 3rd English edition. Elsevier Science BV, Amsterdam. 1006 p.

Marchant R.., Norris R.H., Milligan A. (2006). Evaluation and application of methods for biological assessment of streams: summary of papers. Hydrobiologia, 572: 1-7.

Matsumura-Tundisi T., Leitão S.N., Aghena L.S., Miyahara J. (1990). Eutrofização da represa de Barra Bonita: estrutura e organização da comunidade de Rotifera. Revista Brasileira de Biologia, 50(4) : 923-935.

Moshood K.M. (2009). Zooplankton assemblage of Oyun Reservoir, Offa, Nigeria. Revista de Biologia Tropical, 57(4): 1027-1047.

Niemi G.J., McDonald M.E. (2004). Application of ecological indicators. Annual Review of Ecology, Evolution and Systematics, 35: 89-111.

Ouattara A., Podoor N., Gourène G. (2001). Etudes préliminaires de la distribution spatio-temporelle du phytoplancton dans un système fluvio-lacustre africain (bassin Bia, Côte d'Ivoire). Hydroécologie, Appliquée, 13(1): 113-132.

Ouattara I.N., Ouattara A., Koné T., N'douba V., Gourène G. (2007). Distribution du zooplancton le long de deux petits bassins côtiers ouest africains (Bia et Agnébi ; Côte d'Ivoire). Agronomie Africaine, 19(2): 197-210.

Pai I.K. (2002). Cited in Ecology of Polluted Water. A. Kumar (Ed.). A.P.H. Publishing Corporation, New Delhi. 1250 p.

Parmesan C. (2006). Ecological and evolutionary responses to recent climate change. Annual Review of Ecology, Evolution and Systematics, 637-669.

Pedrozo C.D.A.S., Rocha O. (2005). Zooplankton and water quality of lakes of the Northern Coast of Rio Coast of Rio Grande do Sul State, Brazil. Acta Limnologica Brasiliensia, 17(4): 445-464.

Pourriot R. (1968). Rotifères du Lac Tchad. Bull. I.P.A.N., 30, 2: 471-496. Eaux continentales. Vol. 16, Masson, Paris. 198 p.

Primo A., Kimmel D., Marques S., Martinho F., Azeiteiro U., Pardal M. (2015). Zooplankton community responses to regional-scale weather variability: a synoptic climatology approach. Climate Research, 62(3): 189-198.

R, Core Team. (2015). A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/. Accessed September 28th 2017.

Rey J., Saint-Jean L. (1968). Les cladocères (crustacés ; Branchiopodes) du Tchad. Première note. Cahiers - ORSTOM. Série Hydrobiologie, 2(314): 79-118.

Rey J., Saint-Jean L. (1969). Les cladocères (crustacés; Branchiopodes) du Tchad. Deuxième note. Cahiers - ORSTOM. Série Hydrobiologie, 3(314): 21-42.

Sampaio E.V., Matsumura-Tundisi T., Tundisi J.G. (2002). Composition and abundance of zooplankton in the limnetic zone of seven reservoirs of the Paranapanema River, Brasil. Brazilian Journal of Biology, 62(3): 525-545.

Santos-Wisniewski M., Rocha O., Guntzel A., Matsumura-Tundisi T. (2006). Aspects of the life cycle of Chydorus pubescens Sars, 1901 (Cladocera, Chydoridae). Acta Limnologica Brasiliensia, 18(3): 305-310.

Starling F.L do R.M. (2000). Comparative study of the zooplankton composition of six lacustrine ecosystems in central Brazil during the dry season. Revista Brasileira de Biologia, 60(1): 101-111.

Touzin D. (2008). Utilisation des macroinvertébrés benthiques pour évaluer la dégradation de la qualité de l'eau des rivières au Québec. Faculté des sciences de l'agriculture et de l'alimentation Université Laval Canada. Thèse d'Ingénieur Agronome. 40 p.

Verma J.P. (2002). Ecology and ethology of aquatic biota. Volume 1. Edited by Kumar, A.A.P.H. Publishing Corporation, New Delhi. 372 p.

Walther B.A., Moore J.L. (2005). The concepts of bias, precision, and accuracy, and their use in testing the performance of species richness estimators, with a literature review of estimator performance. Ecography, 28: 815-829.

Yagow G., Wilson B., Srivastava P., Obropta C.C. (2006). Use of biological indicators in TMDL assessment and implementation. Transactions of the American Society of Agricultural and Biological Engineers, 49: 1023-1032.

Zébazé-Togouet S.H., NjinéT., Kemka N., Nola M., Foto Menbohan S., Monkiedje A., Niyitegeka D., Sime-Ngando T., Jugnia B. (2004). Variations spatiales et temporelles de la richesse et de l'abondance des rotifères (Brachionidae et Trichonidae) et des cladocères dans un petit lac artificiel eutrophe situé en zone tropicale. Revue des Sciences de l'eau, 18(4): 485-505.