An assessment of the water quality and ecological status of selected rivers in the Vhembe Biosphere Reserve using diatom based indices, fish biodiversity and the health status of the fish.

1. Introduction

Freshwater resources, and in particular rivers, provide water for agriculture, domestic purposes, mining and other industries. The pollution of these resources is an increasing problem worldwide and the rivers in the Vhembe Biosphere Reserve are no exception (Fouché *et al.* 2012). Over the years a decline in water quality has been observed in particular in urban regions, such as Thohoyandou (Fouché 2013). This decline, due to anthropogenic impacts, has lead to eco-degradation (Ashton *et al*., 2001) which includes a decline in species diversity (Foord and Fouché 2014).

Physico-chemical monitoring, and in particular chemical analyses, has been the backbone of quality monitoring of freshwater resources in many countries including South Africa (DWAF 1986). The results are however representative of conditions at the instant of sampling and do not reflect the temporal water quality trends of a resource such as river. More reliable results would be obtained from frequent and regularly spaced chemical analyses (Harding and Taylor 2011) but this is expensive and expenses increase linearly with an increase in sampling frequency. This, and the fact that riverine biota are directly dependent on their immediate environment, has lead to development and implementation of biological monitoring which has, according to Taylor et al. (2005) the main advantage that it utilises organisms whose exposure to water, and the pollutants therein, is continuous and they would therefore reflect actual impacts, both long and short term, on the resource. Over the past three decades biotic indices have been developed in South Africa and form part of a suite of water quality assessment tools applied in the national River Health Program (Hohls 1996, Strydom et al. 2006 Kleynhans and Louw 2007).

The use of diatoms as bioindicators shows a globally increasing trend (Kelly and Whitton 1995, Lenoir and Coste 1996, Dell' Uomo 1996, Kelly 1998a, Breen 1998) and the effectiveness of using diatoms lies in the simple logic that if bottom-up issues, such as water quality, are being assessed it makes sense to employ an indicator that reflects the direction. Diatoms have historically been extensively studied in southern African river systems (Schoeman 1973, 1982, Passy et al. 1997, Harding et al. 2004) and early efforts were made to relate diatoms to water quality (Archibald 1972). However, the application and evaluation of existing indices (Bate et al. 2002, 2004a, de la Rey et al. 2004, Harding et al. 2005, Taylor et al. 2007b, Walsh and Wepener 2009) and the development of a South African diatom index (Harding and Taylor 2011) are more recent.

Parasites are small, prolific, symbiotic organisms that spend the most of their life cycles in a larger host in a way that harms or is of no advantage to host and range from the microscopic unicellular protozoa to

macroscopic complex multi-celled organisms (Clegg *et al*. 1996). Based on their lifestyles, parasites can either be classified as endo- or ectoparasitic. Aquatic ectoparasites are directly exposed to the surrounding environment while endoparasites are protected in the host's body (Luus-Powell 1997). The presence, or absence, and abundance of parasites can be used as indications of fish health which in turn can be related to the state of the environment. This concept led to the development of the Parasite Index (PI) (Avenant-Oldewage *et al*. 1995) which was been extensively used and refined (Jooste *et al*. 2003, 2005). The PI forms part of the fish Health Assessment Index (HAI) is an inexpensive, simple and rapid assessment biomonitoring tool for environmental conditions (Goede and Barton, 1990; Goede 1992) which has been used to determine the effects of pollution on the environment (Adams *et a*l., 1993). The exact cause of pollution is not determined by the HAI but it can be used in assessing fish health and consequently the health status of the aquatic ecosystem (Heath *et al*., 2004). In South Africa the HAI has been successfully applied in catchments, such as the Olifants River system (Avenant-Oldewage and Marx 2000; Jooste *et al.* 2004).

Fouché *et al*. (2012) has shown that the Mvudi River, which flows into the Nandoni Dam, is polluted by both non-point pollution caused by surface run-off from the town of Thohoyandou and point source pollution from the Thohoyandou Sewage Works. Conversely some reaches of other rivers in the proposed Vhembe Biosphere Reserve, such as the Lutanandwa, and in particular its upper reaches, is less impacted where it exits the lower foothill zones (Fouché 2012). The decline in water work done by Foord and Fouché (2014) also shows that a decrease in water quality led to a decline in fish species in the mainstem and upper reaches of the Luvuvhu River.

The health status of fish and parasite diversity of the smaller fish species in Luvuvhu River tributaries in the Vhembe Biosphere Reserve is relatively unknown. In addition little is known about the current fish diversity, and whether changes have occurred, as well as the water quality status of these rivers. The results and generated data in a study would assist in determining the fish health and parasite diversity and the results can consequently be implemented in the management and conservation of the Vhembe Biosphere Reserve.

The question now arises whether the water quality of the smaller tributaries of the Luvuvhu River system are impaired, and if they are what the trend and the duration, both long and short term, on these resources are. In addition it can be asked whether the parasite diversity and health of selected fish species, are similar in these rivers and whether it relates to the water quality.

It was hypothesized that the water quality of the tributaries that flow through urban areas of the Vhembe Biosphere Reserve is impaired and that a long term pollution trend is reflected by the diatoms and fish.

The study aimed to:

a) Assess water quality and pollution trends of selected tributaries of the Luvuvhu River using diatom and fish based indices.
b) Assess changes in the fish biodiversity and to determine the ecostatus of the rivers.

The objectives of the study were:

- To determine the *in situ* water quality parameters at selected sites in the rivers. These parameters include pH, temperature, Electrical Conductivity, Total Suspended Solids Dissolved Oxygen concentration and saturation.
- To determine the concentrations of the nutrients (nitrite, nitrate, ammonium and phosphate) over a period of time
- Identify the parasites from the selected fish species.
- To determine the health of species by using the HAI.

2. Materials and methods

2.1 The study area and sites

Four sites, at similar altitudes in the same Ecoregion, were selected in the Mvudi, Barotta, Dzindi and Lutanandwa rivers, in the Vhembe Biosphere Reserve. While the two sites in the Barotta and Lutanandwa Rivers were representative of less impacted rivers the other two sites in the other rivers representedo impacted areas.

2.2 Duration of study and sampling frequency

Sampling commenced in April 2014 and continued for six months to include both high and low flow scenarios.

a) *In situ* water quality parameter determination, as well as water sampling and chemical analyses to determine the nutrient content, was done during each survey.
b) Water samples were also collected at each site during the first survey for total chemical analyses by an accredited laboratory
c) During each survey fish were sampled according to the FRAI protocol
d) Collection of fish, parasite sampling and diatom work will be done twice, one during high flow and once during low flow

2.3 Fish sampling

Fish were collected using electro-narcotisation in rheophilic biotopes and with pole seine nets, with a mesh sizes ranging from 10mm stretch mesh, in pools and backwaters. Fish were identified on site using Skelton (2001).

2.4 *In situ* water quality parameters and chemical analyses of water.

Handheld Eutech Cyberscan meters were used to determine the electrical conductivity (EC), Total Dissolved Solids (TDS), pH, dissolved oxygen and water temperature *in situ* at the sampling sites. Water samples were collected in acid-prepared 250 ml bottles that were rinsed on site and placed on ice for transport before storage at 4˚C until analysed in the laboratory for nitrite, nitrate, ammonium and phosphates according to the standard protocol using a Merck Pharo spectrophotometer. During the first survey a second sample was taken at each site and taken to WATERLAB (Pty) Ltd for total chemical analyses. Water samples for microbial analyses were collected in 1L sterilized bottles, placed on ice and taken to the laboratory for analyses.

2.5 Diatom sample collection and preservation

The proposed standardised methodology for epilithic diatom field sampling and laboratory procedures as described by Taylor et al. (2005) was followed. At each sampling site five submerged boulders, cobbles or pebbles were collected from random points in riffles, placed in a sampling tray and *ca* 50ml water added. The diatoms were removed by scrubbing the upper surface with a clean toothbrush. The resulting suspension was mixed well, poured into vials and preserved by adding ethanol to a final concentration of 20% by volume. In the laboratory the diatom samples was prepared for microscopy using the hot hydrochloric acid (HCl) and potassium permanganate ($KMnO_4$) method (Taylor et al. 2005a). Diatoms were identified to species level at the hand of the taxonomic guide provided by Taylor et al. (2007a). Identification was done at a 1000 X magnification on a Nikon E200 light microscope using phase contrast. On each slide 200 individuals, without distinction between valves and frustules, were identified and counted (Taylor et al. 2005a). Because of the large number of diatom based indices in use, the selection of an index was based on what their results represent (Taylor et al. 2007b) or in which biotopes they can be applied. In this study four diatom based indices and the Water Quality Index (WQI) will be used to determine water quality and eutrophication. The diatom based indices applied were: the Biological Diatom Index (BDI) (Lenoir and Coste 1996), Specific Pollution sensitivity Index (SPI) (Coste et al. 1991), Trophic Diatom Index (TDI) (Kelly and Whitton 1995) and the Percentage pollution Tolerant Valves (% PTV) (Kelly 1998a).

2.6 Fish health and parasites

Health Assessment Index (HAI)

The fish were placed in holding tanks filled with river water to diminish stress before they are examined. One fish was removed at a time to do the HAI and PI. Firstly, skin smears made using glass slides, and then checked for ectoparasites using a Nikon stereo-microscope. Visible parasites from the external surface of the collected fish specimens were removed and placed in glass bottles containing water.

Blood was drawn from each specimen using a medical syringe and then used to fill capillary tubes of which the one end will be plugged using commercial Critoseal^{TM} clay. The capillary tubes were centrifuged in a Micro-haematocrit centrifuge for approximately five minutes to separate the blood in plasma and red blood cells. The haematocrit values were then read using a haematocrit reader. The fish were examined externally according to the HAI variables on a field table and the data was recorded on data sheets. The fish was then weighed and the total and standard length measured for later use to determine the condition factor. The fish was then dissected and the gills, eyes and gut of the fish removed and placed in separate labeled Petri dishes containing river water. All internal organs was assessed with the aid of the colour chart developed by Watson (2001) and values ranging from 0-30 according to Health Assessment Index (HAI) were assigned to each organ according to the HAI field score sheet (Jooste *et al.,* 2004).

Numerical values were allocated to each organ according to the classifications of Jooste *et al*. (2004). The variables of the HAI were presented with a value ranging from 0-30, depending on the ailment of the organs tested. For abnormalities found in the eyes, gills, kidney, liver and spleen, a value of 30 was allocated. For the other variables (skin and fins), abnormalities were rated as 10, 20 or 30 subject to the degree of irregularity, the greatest abnormality was ranked as 30. To calculate the index value in a sample, all numerical values for all variables were summed. To calculate the HAI for a sample population all individual fish health index values were added and divided by the total number of fish examined.

Identification and preservation of the parasites

Smears from the skin, fins and gills on glass slides were examined for ectoparasites, such as *Dolops,* using a Nikon light the microscope on site. The gills and eyes were examined for ectoparasites e.g. monogeneans using a dissection microscope. Dissected fish were examined for endoparasites in the gut and muscle for encysted helminthes. Further examinations of the internal organs (liver, spleen, kidney, swim-bladder, and brain) were done using a dissection microscope.

The monogeneans collected were preserved in 70% ethanol while specimens intended for the measurement of the anchors and marginal hooks were mounted in glycerin jelly and sealed with a clear nail varnish on labeled glass slides. Parasites which will not be used for whole mounts were preserved 4% formaldehyde.

Digeneans were placed in a 0,8% saline solution and shaken vigorously to remove excess debris. The organisms were fixed flat between two glass slides in AFA for at least 10 minutes and preserved in ethanol (70%). Cestodes were fixed and stored in formaldehyde. Nematodes were fixed in glacial acetic acid and preserved in 70% ethanol. Acanthocephalans, pentastomids, branchiurans and copepods were be fixed and stored in 70% ethanol.

The condition factor (CF)

The Condition Factor (CF), a value used to designate fish health (Anene 2005) and a factor that allows comparison of the condition of individual fish within a population, or individual fish from different populations and/or two or more populations from different localities were calculated according to Heath *et al*. (2004), where:

$$CF = W \times 10^5 / L^3$$

(W = weight in g; L = standard length in cm)

The standard deviation for each sample will be calculated as proposed by Adams *et al*. (1993).

The parasite index (PI)

The presence, and consequently the abundance, of parasites form the basis of the Parasite Index (PI) in the Health Assessment Index (Avenant-Oldewage *et al.,* 1995; Jooste *et al.*, 2003; 2005). In good water quality, a count of 10 to 20 ectoparasites can be expected using the PI, but the count will drop to two, one, or even zero if the water quality is poor (Avenant-Oldewage 1998). Therefore the Inverted Parasite Index (IPI) for ectoparasites has been developed by Avenant-Oldewage and applied by Crafford and Avenant-Oldewage (2009) on the sharptooth catfish in Vaal River System. Both the PI and IPI was used in this study.

TABLE 1: The revised Parasite Index (PI) (Jooste *et al*., 2004) and Inverted Parasite Index (IPI) (Crafford and Avenant-Oldewage 2009).

Ectoparasites			**Endoparasites**	
Number	**PI**	**IPI**	**Number**	**PI**
0	0	30	0	0
1-10	10	30	<100	10
11-20	20	20	101-1000	20
>21	30	10	>1000	30

3. Preliminary results

3.1 Number of surveys

Five surveys were conducted at the four main sites namely in April, May, June, July and August 2014. A fifth site (Lower Dzindi) was added as a comparative site for that river. The four selected sites are shown in Table 2.

Table 2: The selected sites in the Luvuvhu River Tributaries

Site number	**Site name**	**River**
SARCHI 1	Ravele	Barotta
SARCHI 2	Upper Dzindi	Dzindi
SARCHI 3	Carwash	Mvudi
SARCHI 4	Lutanandwa	Lutanandwa

3.2 *In situ* water quality

Table 3 shows the *in situ* water quality parameters recorded at the sites during the survey.

Table 3: The *in situ* water quality parameters.

	APRIL				
	SARCHI 1	**SARCHI 2**	**SARCHI 3**	**SARCHI 4**	
	Ravele	**Upper Dzindi**	**Carwash**	**Lutanandawa**	**Lower Dzindi**
Time	**11**	**8**	**12**	**8**	**11**
Altitude	670	666	538	655	562
pH	6.66	7.06	6.77	6.62	6.63
Conductivity uS	61.6	57.3	132.5	78	83.7
Oxygen%	87.2	98.2	87.3	94.9	95.1
Oxygen mgl	7.38	9.54	7.79	9.05	8.51
TDS	30.8	28.6	66.2	39.3	41.7
Temperature	22.4	16.5	18.8	16.7	19.7
Flow	3	3	2	3	3
Clarity	1	1	2	1	1
	MAY				
	SARCHI 1	**SARCHI 2**	**SARCHI 3**	**SARCHI 4**	**SARCHI 5**
	Ravele	**Upper Dzindi**	**Carwash**	**Lutanandawa**	**Lower Dzindi**
Time	**10**	**13**	**14**	**8**	**12**
Altitude	670	666	538	655	562
pH	6.85	7.38	7.39	7.27	8.01
Conductivity uS	64.2	57.9	133.7	82.2	87.7
Oxygen%	96.09	95.5	84.2	97.7	99.1
Oxygen mgl	9.2	8.57	7.64	9.67	9.26
TDS	31.9	30.9	66.9	41.6	43.8
Temperature	17.9	19.9	17.9	15.3	17.5
Flow	3	2	2	3	2
Clarity	1	1	2	2	2
	JUNE				
	SARCHI 1	**SARCHI 2**	**SARCHI 3**	**SARCHI 4**	**SARCHI 5**
	Ravele	**Upper Dzindi**	**Carwash**	**Lutanandawa**	**Lower Dzindi**
Time	**9**	**11**	**13**	**8**	**10**
Altitude	670	666	538	655	562
pH	6.33	6.46	6.63	6.81	6.39
Conductivity uS	64.2	65.5	130.7	84	91.8
Oxygen%	99.3	99.9	87.8	100.9	98.4
Oxygen mgl	9.87	9.64	8.31	10.23	9.61
TDS	32.2	32.7	65	14.4	45.8
Temperature	16		15.5	41.9	16.3
Flow	2	2	2	2	2
Clarity	1	1	2	1	1

Table 3 (cont.): The *in situ* water quality parameters

	JULY				
	SARCHI 1	SARCHI 2	SARCHI 3	SARCHI 4	SARCHI 5
	Ravele	**Upper Dzindi**	**Carwash**	**Lutanandawa**	**Lower Dzindi**
Time	**11**	**8**	**8**	**10**	**12**
Altitude	670	666	538	655	562
pH	6.53	6.51	6.56	6.49	6.33
Conductivity uS	61.8	68.8	136.9	85.9	95.5
Oxygen%	97.8	96.8	92.6	98.8	100.9
Oxygen mgl	9.33	10.2	9.39	9.53	8.96
TDS	30.8	34.3	69	42.8	47.7
Temperature	17.4	12.9	14.3	15.4	15.6
Flow	1	1	1	2	1
Clarity	1	1	2	1	2
	SARCHI 1	SARCHI 2	SARCHI 3	SARCHI 4	SARCHI 5
	Ravele	**Upper Dzindi**	**Carwash**	**Lutanandawa**	**Lower Dzindi**
Time	**10**	**12**	**13**	**8**	
Altitude	670	666	538	655	562
pH	6.37	6.55	6.73	7.05	6.81
Conductivity uS/cm	66.4	69.9	158.7	90	100.9
Oxygen%	94.6	96.6	80.7	85	90.9
Oxygen mgl	9.13	8.47	7.36	8.49	8.44
TDS	33.2	35.3	78.9	45.9	50.2
Temperature	16.6	19.1	17.2	14.2	17.6
Flow	2	2	2	2	2
Clarity	1	1	3	1	2

3.3 Water chemistry

The results of the chemical analyses of the water sample taken during the first survey are shown in Appendix 1.

Table 4 shows the results obtained with the nutrient analyses and it is in particular the high Ammonium and nitrate values at sites 3 and 4 that are noteworthy. It should also be noted that these results coincide with the high TDS and EC values shown in Table 3. The two analyses clearly indicate that these sites were polluted during the times of the survey.

Table 4: Results of the nutrients analyses of the water samples collected at the sites.

Site no.	Site name	Date	Ammonium	Nitrate	Nitrite	Phosphate
1	Ravele	29/04/2014	0.13	1	0.03	0.19
2	Upper Dzindi	30/04/2014	0.15	0.03	0.03	0.18
3	Carwash	30/04/2014	**0.54**	**0.9**	0.04	0.12
4	Lutanandwa	01/05/14	0.13	1.3	0.04	0.13
5	Lower Dzindi	01/05/14	**0.22**	0.7	0.03	0.09
1	Ravele	26/05/2014	0.17	1	0.04	0.19
2	Upper Dzindi	26/05/2014	0.2	0.9	0.06	0.08
3	Carwash	26/05/2014	**0.50**	**0.7**	0.06	0.16
4	Lutanandwa	26/05/2014	0.11	1.2	0.04	0.11
5	Lower Dzindi	26/05/2014	0.1	0.7	0.04	0.19
1	Ravele	19/06/2014	0.16	0.9	0.03	0.17
2	Upper Dzindi	19/06/2014	0.35	0.4	0.04	0.12
3	Carwash	19/06/2014	0.76	1	0.07	0.2
4	Lutanandwa	19/06/2014	0.21	1.2	0.04	0.1
5	Lower Dzindi	19/06/2014	0.14	0.8	0.004	0.15
1	Ravele	21/07/2014	0.19	1	0.04	0.14
2	Upper Dzindi	22/07/2014	0.13	0.8	0.04	0.1
3	Carwash	21/07/2014	0.59	0.9	0.06	0.16
4	Lutanandwa	20/07/2014	0.08	1.3	0.04	0.13
5	Lower Dzindi	22/07/2014	0.17	0.8	0.04	0.13
1	Ravele	28/08/2014	0.21	1.3	0.05	0.22
2	Upper Dzindi	28/08/2014	0.36	0.7	0.04	0.23
3	Carwash	28/08/2014	1.83	1.5	0.09	0.37
4	Lutanandwa	28/08/2014	0.11	0.6	0.03	0.14
5	Lower Dzindi	28/08/2014	0.24	0.9	0.05	0.23

3.4 Macro-invertebrates

Macro-invertebrate surveys were conducted during the April and July surveys and the diversity and abundance are shown in Appendix 2.

3.5 Fish

The fish diversity and abundance observed at the sites are shown in appendix 3.

3.6 Diatoms

The diatom samples collected during the four surveys have been forwarded to Dr Jonathan Taylor for sample preparation and the slides will be viewed and analysed when returned.

3.7 Parasites

Parasites were collected from specimens of the ten species shown in Table 5.

Table 5: The fish species that were examined for ecto- and endoparasites.

Fish species		Sites							
	N	Barotta		Dzindi		Mvudi		Lutanandwa	
		May	July	May	July	May	July	May	July
Amphilius uranoscopus,	64	12	10	10	9	2	1	10	10
Chiloglanis pretoriae	56	10	8	10	10	10	4	10	4
Barbus eutaenia,	12		3			5	2		2
Barbus lineomaculatus	35			7	7	8	10	2	1
Barbus neefi	1				1				
Barbus paludinosus	5			1		2		2	
Labeo cylindricus	10		1			1	3	3	2
Labeobarbus marequensis	36	4	10				2	10	10
Clarias gariepinus	1				1				
Tilapia sparrmanii	1								1

Several different groups of parasites (ecto- and endoparasites) were recorded from the different fish species. These will later (after data analysis) be grouped per fish species and site. Several parasites have not been identified to species level yet as some may require molecular work (work in progress). The monogenean from the gills of *C. pretoriae* is preliminary identified as *Synodontella* sp. for the purpose of this report, but we are of the opinion that it might be a new genus and needs further work. Furthermore, the adult digenean from the intestine of *A. uranoscopus* is preliminary identified as *Emoleptalea* sp. although this identification is not definite as this stage.

Monogeneans are parasitic flatworms found mostly on the gills and fins (skin) of freshwater fish and several ‘endo-monogeneans present in fish, e.g. *Enterogyrus* from the stomach of chichlids. Digeneans are endoparasitic flatworms, usually with two suckers for attachment. They are commonly found in the digestive tract but (especially encysted larval stages) occur throughout the organs systems of all vertebrates. During this study, all digeneans, except *Nematobothrium* sp. from the orbit of *L. cylindricus*, and *Emoleptalea* sp. (from the intestine of *A. uranoscopus*), were larval forms (adults will be found in piscivorous birds or reptiles). Unidentified digenean larvae were found from the body cavity, muscle, fin and skin of all the fish species and further work (most probably molecular work) is needed to identify this digenean.

Nematodes are parasitic roundworms found in al organs of vertebrates and invertebrates. During this study and an unidentified adult nematode from the intestine and *Contracaecum* larvae from the body cavity of *A. uranoscopus* were recorded. Leeches are blood-sucking segmented annelids and found in aquatic and terrestrial environments. An unidentified leech was recorded from the fins of *L. cylindricus* and *A. uranoscopus* during this study.

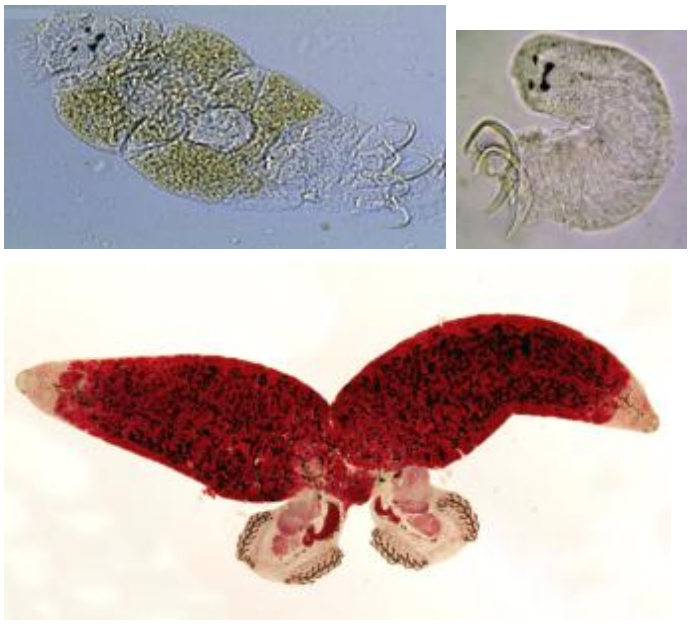

Figure 1: Top left: *Synodontella* sp. (from the gills of *C. pretoriae*); Top right: *Dactylogyrus spincirrus* (from the gills of *L. marequensis*); Bottom: *Afrodiplozoon* sp. (from the gills of *L. marequensis*); photo credit Dr Iva Přikrylová.

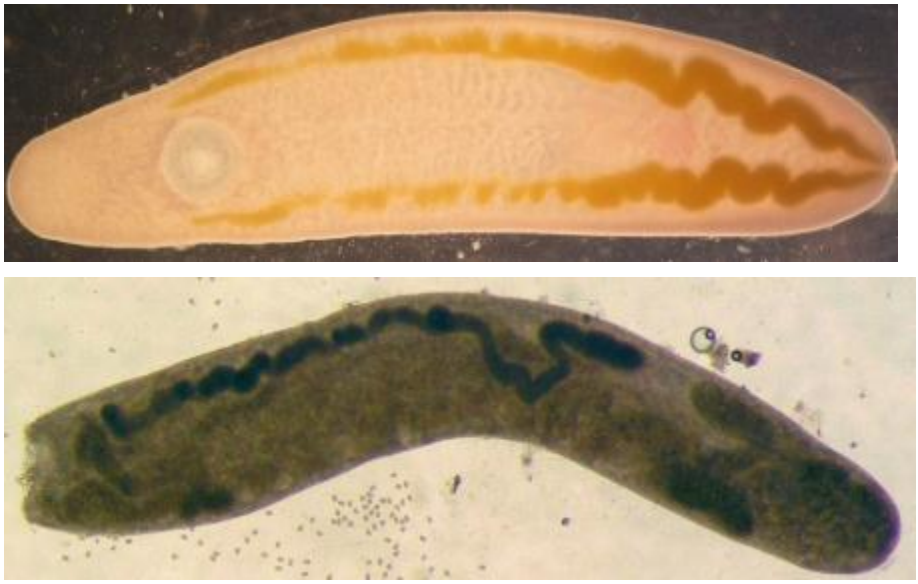

Figure 2: Top: *Clinostomum* sp. (from the body cavity of *A. uranoscopus, C. pretoriae* and *L. marequensis*); Bottom: *Nematobothrium* sp. (from the orbit of *L. cylindricus*).

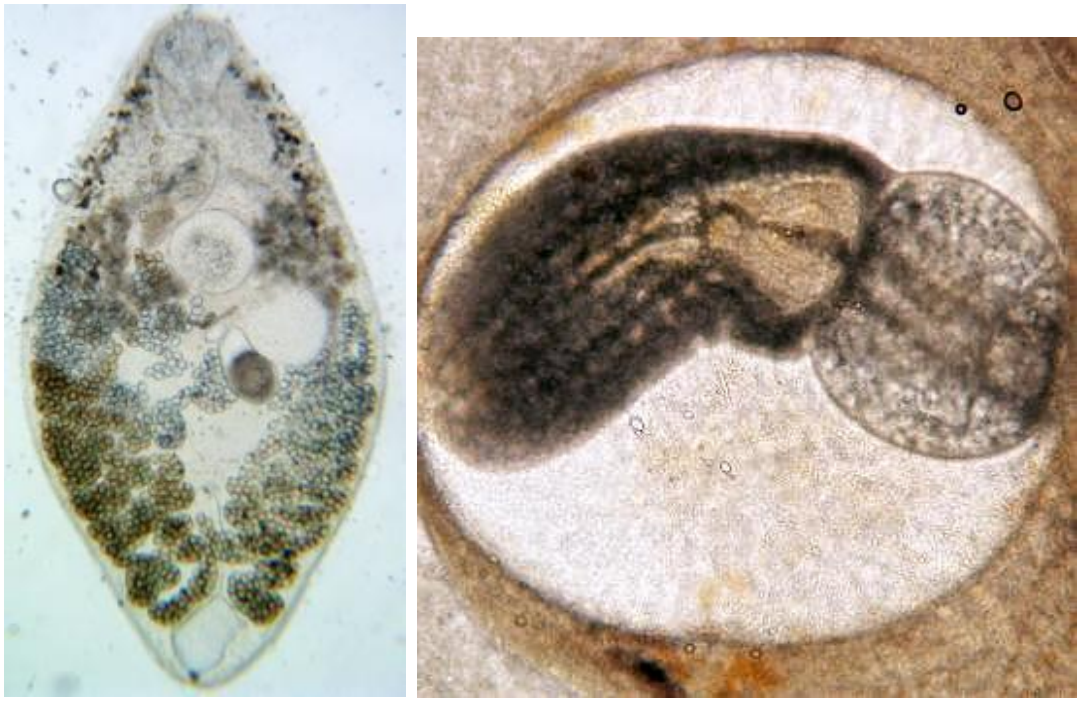

Figure 3: Left: *Emoleptalea* sp. (from the intestine of *A. uranoscopus*); Right: *Diplostomum* sp. (from the eye of *L. cylindricus, B. lineomaculatus, A. uranoscopus* and *C. pretoriae*).

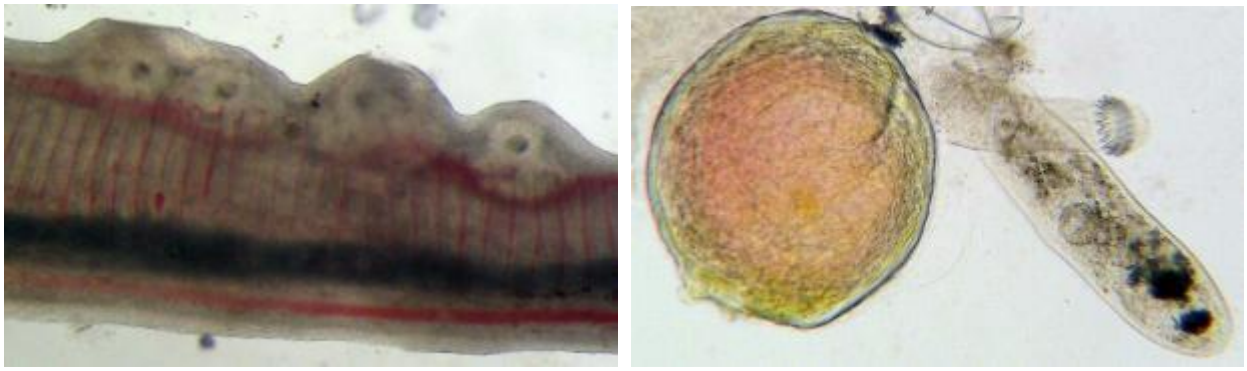

Figure 4: Echinostome larvae (from the mesentries of *L. cylindricus* and gills of *B. lineomaculatus*).

Figure 5: *Contracaecum* larvae from the body cavity of *A. uranoscopus*.

Figure 6: Leech from the skin and fins of *L. cylindricus* and *A. uranoscopus*.

3.7 Outstanding results

At this point the following results are outstanding:

- Diatom analysis and calculation of relevant indices
- FRAI results
- Microbiological analyses of the water samples.

3.8 Participants in the project and capacity building.

a) Participants

Prof Paul Fouché (UNIVEN)

Prof Wilmien Luus-Powell (UL)

Dr Moses Matla (UL)

Dr Sareh Tavakol (Post doc fellow, UL)

Dr Iva Prĭkrylová (Research Associate, UL)

b) Capacity building

- Student participation as field assistants

  Mr Dumisani Khosa (MSc student - Univen)

  Mr Lincon Chavalala (MSc student - Univen)

- Post graduate research in the project

  Ms Magdeline Takalo (Hons student - UL)

  Ms Rhee Molele (MSc student - UL)

  Ms Khensani Ncube (MSc student - UL)

3.9 Reporting and publication

All three postgraduate students of UL have presented their findings at the annual Science Workshop of the University of Limpopo.

Two publications are in preparation:

- One reporting on the new parasite species recorded.
- The other will report on the ecosystem health of the four tributaries.

Appendix 1

	Ag (mg/L)	Al (mg/L)	As (mg/L)	Au (mg/L)	B (mg/L)	Ba (mg/L)	Be (mg/L)	Bi (mg/L)	Ca (mg/L)	Cd (mg/L)	Ce (mg/L)	Co (mg/L)
Latonyanda	0.000	0.048	0.000	0.000	0.006	0.013	0.000	0.000	5.71	0.000	0.000	0.000
Car Wash	0.000	0.014	0.000	0.000	0.008	0.037	0.000	0.000	11.20	0.000	0.000	0.001
Upper Dzindi	0.000	0.008	0.000	0.000	0.003	0.006	0.000	0.000	4.67	0.000	0.000	0.000
Ravele	0.001	0.019	0.000	0.000	0.024	0.019	0.000	0.000	4.36	0.000	0.000	0.000
	Cr (mg/L)	**Cs (mg/L)**	**Cu (mg/L)**	**Dy (mg/L)**	**Er (mg/L)**	**Eu (mg/L)**	**Fe (mg/L)**	**Ga (mg/L)**	**Gd (mg/L)**	**Ge (mg/L)**	**Hf (mg/L)**	**Ho (mg/L)**
Latonyanda	0.000	0.000	0.001	0.000	0.000	0.000	0.515	0.002	0.000	0.000	0.000	0.000
Car Wash	0.000	0.000	0.001	0.000	0.000	0.000	0.707	0.005	0.000	0.000	0.000	0.000
Upper Dzindi	0.000	0.000	0.001	0.000	0.000	0.000	0.234	0.001	0.000	0.000	0.000	0.000
Ravele	0.000	0.000	0.001	0.000	0.000	0.000	0.167	0.004	0.000	0.000	0.000	0.000
	In (mg/L)	**Ir (mg/L)**	**K (mg/L)**	**La (mg/L)**	**Li (mg/L)**	**Lu (mg/L)**	**Mg (mg/L)**	**Mn (mg/L)**	**Mo (mg/L)**	**Na (mg/L)**	**Nb (mg/L)**	**Nd (mg/L)**
Latonyanda	0.000	0.000	0.585	0.000	0.000	0.000	3.51	0.011	0.000	5.66	0.000	0.000
Car Wash	0.000	0.000	0.424	0.000	0.000	0.000	6.07	0.254	0.000	9.71	0.000	0.000
Upper Dzindi	0.000	0.000	0.174	0.000	0.000	0.000	3.22	0.012	0.000	4.46	0.000	0.000
Ravele	0.000	0.000	0.385	0.000	0.000	0.000	2.40	0.022	0.000	3.71	0.000	0.000
	Ni (mg/L)	**Os (mg/L)**	**P (mg/L)**	**Pb (mg/L)**	**Pd (mg/L)**	**Pt (mg/L)**	**Rb (mg/L)**	**Rh (mg/L)**	**Ru (mg/L)**	**Sb (mg/L)**	**Sc (mg/L)**	**Se (mg/L)**
Latonyanda	0.005	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
Car Wash	0.007	0.000	0.010	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
Upper Dzindi	0.002	0.000	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004
Ravele	0.002	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	-0.001
	Si (mg/L)	**Sm (mg/L)**	**Sn (mg/L)**	**Sr (mg/L)**	**Ta (mg/L)**	**Tb (mg/L)**	**Te (mg/L)**	**Th (mg/L)**	**Ti (mg/L)**	**Tl (mg/L)**	**Tm (mg/L)**	**U (mg/L)**
Latonyanda	1.409	0.000	0.000	0.018	0.000	0.000	0.000	0.000	0.006	0.000	0.000	0.000
Car Wash	1.477	0.000	0.000	0.042	0.000	0.000	0.000	0.000	0.009	0.000	0.000	0.000
Upper Dzindi	1.105	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000
Ravele	2.116	0.000	0.000	0.025	0.000	0.000	0.000	0.001	0.005	0.000	0.000	0.000
	V (mg/L)	**W (mg/L)**	**Y (mg/L)**	**Yb (mg/L)**	**Zn (mg/L)**	**Zr (mg/L)**						
Latonyanda	0.001	0.000	0.000	0.000	0.003	0.000						
Car Wash	0.000	0.000	0.000	0.000	0.005	0.000						
Upper Dzindi	0.000	0.000	0.000	0.000	0.004	0.000						
Ravele	0.001	0.012	0.000	0.000	0.008	0.000						

Appendix 2

	Ravele-29/04/2014			Dzindi-30/04/2014			Lutanandwa-01/05/2013			Carwash-30/04/2014		
Taxon	Stone	VEG	GSM	Stone	VEG	GSM	Stone	VEG	GSM	Stone	VEG	GSM
Aeshnidae				4			1					
Amphipoda				1								
Athricidae				2								
Atyidae	9		20					2				
Baetidae	18	11	7	12	14	2	23	14	8	15	8	5
Chironomidae			6	1						6	3	21
Chorocyphidae	1			2			2					
Coenagrionidae										18		
Gomphidae			4	6		6	2	1	4			
Heptagennidae				32								
Hydropsychidae	36			48	11	1	7		2			
Leptophlebiidae	7		1									
Libellulidae	1			1	2							
Muscidae				2								
Naucoridae				1					5		3	1
Notonectidae					1							
Parecnomidae	1											
Potanautidae	3		1	10	2	1			3	1		1
Simulidae						1	1			9	2	
Tabanidae	1			6			2					
Tricorythidae	60			45	7	1	1					
Vellidae	3	3										

	Ravele-21/07/2014			Dzindi-22/07/2014			Lutanandwa-20/07/2014			Carwash-21/07/2014		
Taxon	Stone	VEG	GSM	Stone	VEG	GSM	Stone	VEG	GSM	Stone	VEG	GSM
Athericidae	4		1	2			3					
Atyidae	1	3			1				1			
Baetidae	10	4	4	24	12		17	25	11	36	5	7
Chironomidae										12		6
Chlorocyphidae	3	1		1				1			13	2
Coenagrionidae		1										
Cordullidae												1
Gerridae	2				2							
Gomphidae			1	6		3	7		9			
Gyrinidae	1											
Heptagennidae	26	3		17	1		10					
Hydropsychidae	12		1	26	3		41	9	8	13		
Libellulidae	2			2			7			2		
Naucoridae									3	32		
Notonectidae						1	3					
Oligochaeta												32
Phsychomyiidae	2											
Physidae											1	1
Potamonautidae	1	1		2			2					
Psephenidae	1			1								
Simulidae					2		2			27	4	
Tabanidae				6		1	2					
Tricorythidae	65	3		37	1		29					
Veliidae		1			1							

Appendix 3

	APRIL				MAY				JUNE			
	SARCHI 1	SARCHI 2	SARCHI 3	SARCHI 4	SARCHI 1	SARCHI 2	SARCHI 3	SARCHI 4	SARCHI 1	SARCHI 2	SARCHI 3	SARCHI 4
	Ravele	**Upper Dzindi**	**Carwash**	**Latonyan-da**	**Ravele**	**Upper Dzindi**	**Carwash**	**Latonyan-da**	**Ravele**	**Upper Dzindi**	**Carwash**	**Latonyan-da**
AMOS												
AURA	16	26	3	18		24	2	20	14	20	2	12
BEUT		2	4	3	16		7		3		1	
BLIN		30	11	2	9	31		1	5	14	10	
BNEE												
BPAU												
BTRI			4									
BUNI			5								2	
BVIV	1				3				1			
CGAR			1				1					
CPAR												
CPRE	20	14	1	9	5	10		7	8	9		5
LCYL	2		2	3	1				1		1	1
LMAR	8	2		11	16			3	18			21
LMOL												
MACU												
MBRE												
MMAC												
OMOS												
OPER												
PCAT												
PPHI			1	4					1			
TREN												
TSPA				4		1		1	1		2	31
Diversity	5	5	8	8	6	4	3	4	9	3	6	5

	JULY					AUGUST			
	SARCHI 1	SARCHI 1	SARCHI 2	SARCHI 3	SARCHI 4	SARCHI 1	SARCHI 2	SARCHI 3	SARCHI 4
	Ravele	**Ravele**	**Upper Dzindi**	**Carwash**	**Latonyan-da**	**Ravele**	**Upper Dzindi**	**Carwash**	**Latonyan-da**
AMOS									
AURA	16	31	32	1	13	16	19		21
BEUT		9		5	2	8		1	1
BLIN		7	14	16	1	6	15	2	3
BNEE			3						
BPAU									
BTRI						1			
BUNI									
BVIV	1								
CGAR			1	2				1	
CPAR						15			
CPRE	20	8	16	4	4		10		2
LCYL	2	1		3	2				1
LMAR	8	32	3	3	24	29	12		35
LMOL									1
MACU									21
MBRE									
MMAC									
OMOS									
OPER									
PCAT									
PPHI									1
TREN									
TSPA					2	1			1
Diversity	5	6	6	7	7	6	4	3	10