An Ichthyological and Bio-monitoring Survey of Fish Assemblages in the Vunduzi River from it Source on Gorongosa Mountain to its Lower Reaches in the Gorongosa National Park, Moçambique

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TABLE OF CONTENTS

LIST OF FIGURES

List of Tables

Page Number

General introduction

The Gorongosa National Park (GNP) is situated within the Sofala Province in the central part of Moçambique and located within the co-ordinates 18° 10'S - 19° 20' S and 34° - 35°E (Figure 1) (Tinley 1977; Arvidsson *et al.,* 2011). During 1967 to 1976 the GNP was renowned for its ecological diversity and its high abundance of mammals, especially large herbivores and lions. First established in 1967 the official demarcation of the Park occurred in 1969 (Beilfuss, 2006). During the civil conflict (1976-1992) the existing infrastructure in the Park was either damaged or destroyed and the flora and fauna seriously affected with the numbers of some large mammals reduced by as much as 95% and the decimation of others (Böhme, 2005). Since the end of the civil war there has been a concerted effort by the Mozambican government and an American non-profit organisation, the Carr Foundation, to rehabilitate the Park through the banning of activities such as placer mining and poaching whilst implementing efforts to re-establish management and conservation strategies that has seen to the reconstruction of infrastructure and restocking of wildlife. Restoration began in 1994, with the Park reopening in 1995, which gained momentum with the signing of a 20-year commitment between the Carr Foundation and the Moçambique government in 2008 (Beilfuss, 2006; Gorongosa National Park, 2009).

The GNP comprises a demarcated 3 770 km^2 area, located within the southernmost reaches of the East African Rift System that extends from Ethiopia down into central Moçambique, and the Gorongosa Mountain, which is an isolated 600 km^2 cretaceous granitic intrusive complex (Massif) 1 863 m asl (Arvidsson *et al*., 2011). The mountain extends 30 km in a North-South direction and 20 km in an East-West direction having slopes of approximately 30-40 degrees (Böhme, 2005). Due to its size and *inselberg* nature of Gorongosa Mountain the mountain receives up to 2000 mm precipitation per annum due to orographic rainfalls (Tinley, 1977; Steinbruch and Merkel, 2008). The lush forests and grasslands on its upper latitudes absorb much of that water while the runoff descends the mountain *via* a network of tributaries, streams and rivers. Rivers that meander down the mountain and cross the Báruè Midlands and Park boundaries find their way to Lake Urema, which is located in the middle of the rift valley floor (Urema Rift) 12 km south from the northern border of the Park [web 1]. The lake forms one of the most important ecological features of the GNP (Böhme, 2005).

The water balance in Lake Urema is regulated by rivers having their origins from Mount Gorongosa, the Báruè and Cheringoma Plateau (Figure 1 and 2). Lake Urema is a shallow reservoir lake that is impounded by alluvial fans (Böhme *et al*., 2006) and the extent by which the shoreline retracts and

swells can vary between 10 km^2 and 200 km^2 during periods of no and maximum flooding respectively (Tinley, 1977). Seasonal fluctuation and water sources are indispensable at ensuring the existence of the vast ecosystem of floodplains, grassland and woodlands (Arvidsson *et al*., 2011).

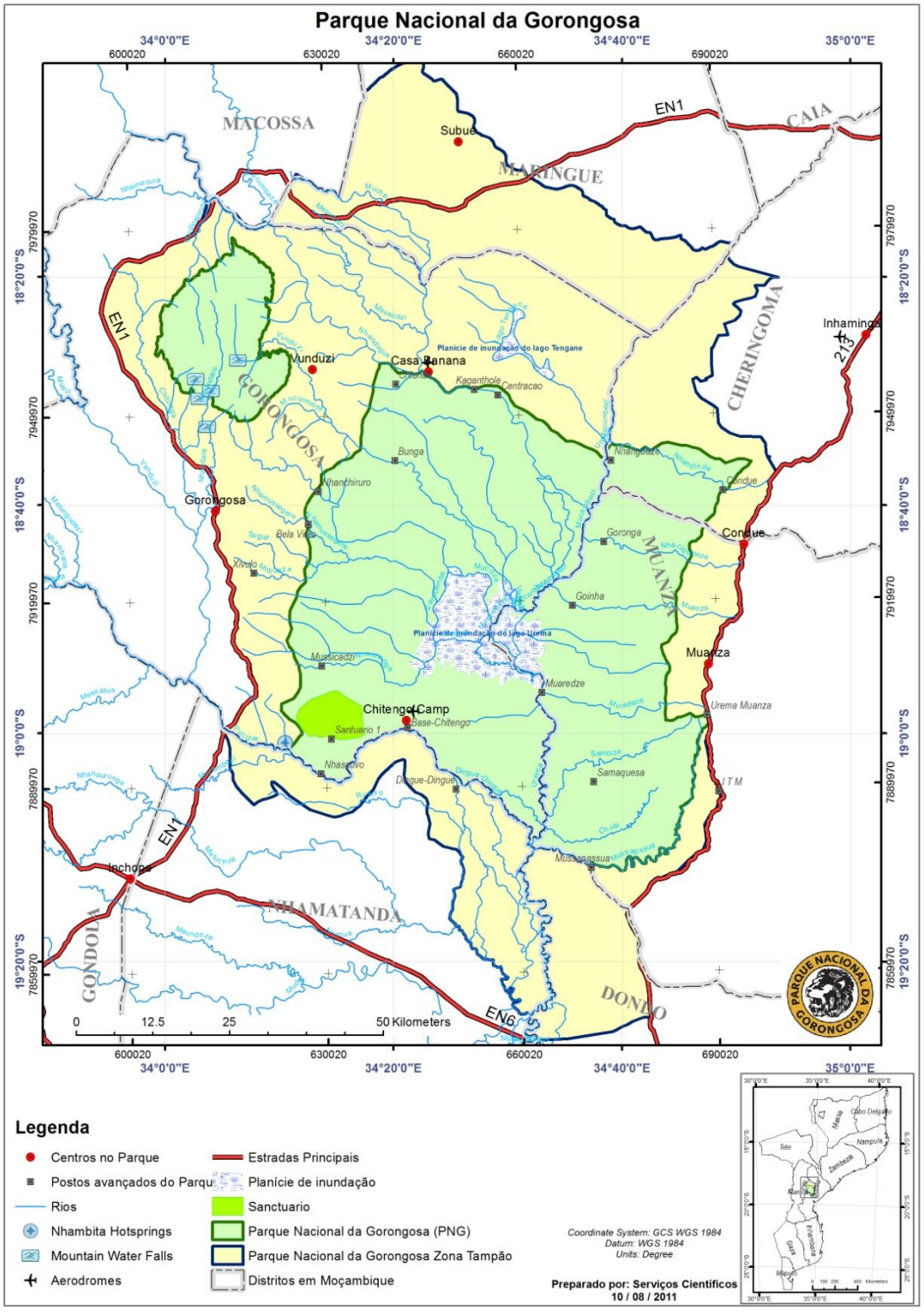


Figure 1: Map showing the boundaries of the Gorongosa National Park, Mount Gorongosa and the surrounding buffer zone. Chintengo is the main camp in the Park.

From the western margins of the Urema Rift the Vunduzi and the Nhandungue River, the latter receiving inflow from the smaller perennial Muera River, feeds Lake Urema all year round to ensure a positive water balance. The source of Vunduzi and Meura rivers originates on Mount Gorongosa. Once the Muera converges with the Nhandungue both the Vunduzi and Nhandungue River cross the Báruè Plateau on their way down to the valley. The Mucodza and Sungue rivers originates from the Báruè Plateau and discharges directly into the lake. The Mucombeze River originates from the rift valley floor and after its confluence with the Nhandugue River, it forms an extensive delta with the Mucodza and the Vunduzi at the head of Lake Urema (Böhme, 2005).

From the eastern margin several smaller rivers flow from the Cheringoma Plateau into the lake. The Muaredzi River deposits sediments near the outlet of the lake slowing its drainage which in turn causes Lake Urema to swell greatly during the rainy season. Water that makes its way past this alluvial fan exists Lake Urema by draining into the Urema River and then into the Pungue River (Böhme, 2005). This outflow eventually reaches the Indian Ocean some 80 km away. The Urema Rift Valley receives 840 mm rainfall (Tinley, 1977; Steinbruch and Merkel 2008) and the centripetal drainage from both the mountain and rift valley forms part of the Urema Catchment, which covers an area of about 8 755 km^2 (Böhme, 2005).

Areas around the mountain and rivers are heavily populated as they represent land favourable for agricultural production (Beilfuss, 2006). For this reason humans have formed an integral part of the Gorongosa ecosystem for millennia, pursuing livelihoods as hunters, gatherers, farmers, and fishermen. An estimate of about 250 000 people live in small communities scattered within Lake Urema's catchment [web 1]. Twenty five thousand thereof live along the fringes of the Park's boundaries while 10 000 – 15 000 inhabit the Park along the eastern base of Mount Gorongosa and the Park's eastern border (Lynam *et al*., 2003).

The most serious impact to the Greater Gorongosa Ecosystem is occurring on Mount Gorongosa. It is estimated that more than 2 000 people live on the mountain [web 1]. More than 550 households are living on steep slopes above 700 m in pristine montane forest that until recently was considered sacred and off-limits by local tradition (Beilfuss, 2007). On the mountain, due to the use of a slash-and-burn approach, subsistence agriculture and uncontrolled land use is rapidly destroying the forest with most households clearing small plots of land only to be abandoned once the soil becomes infertile and unproductive.

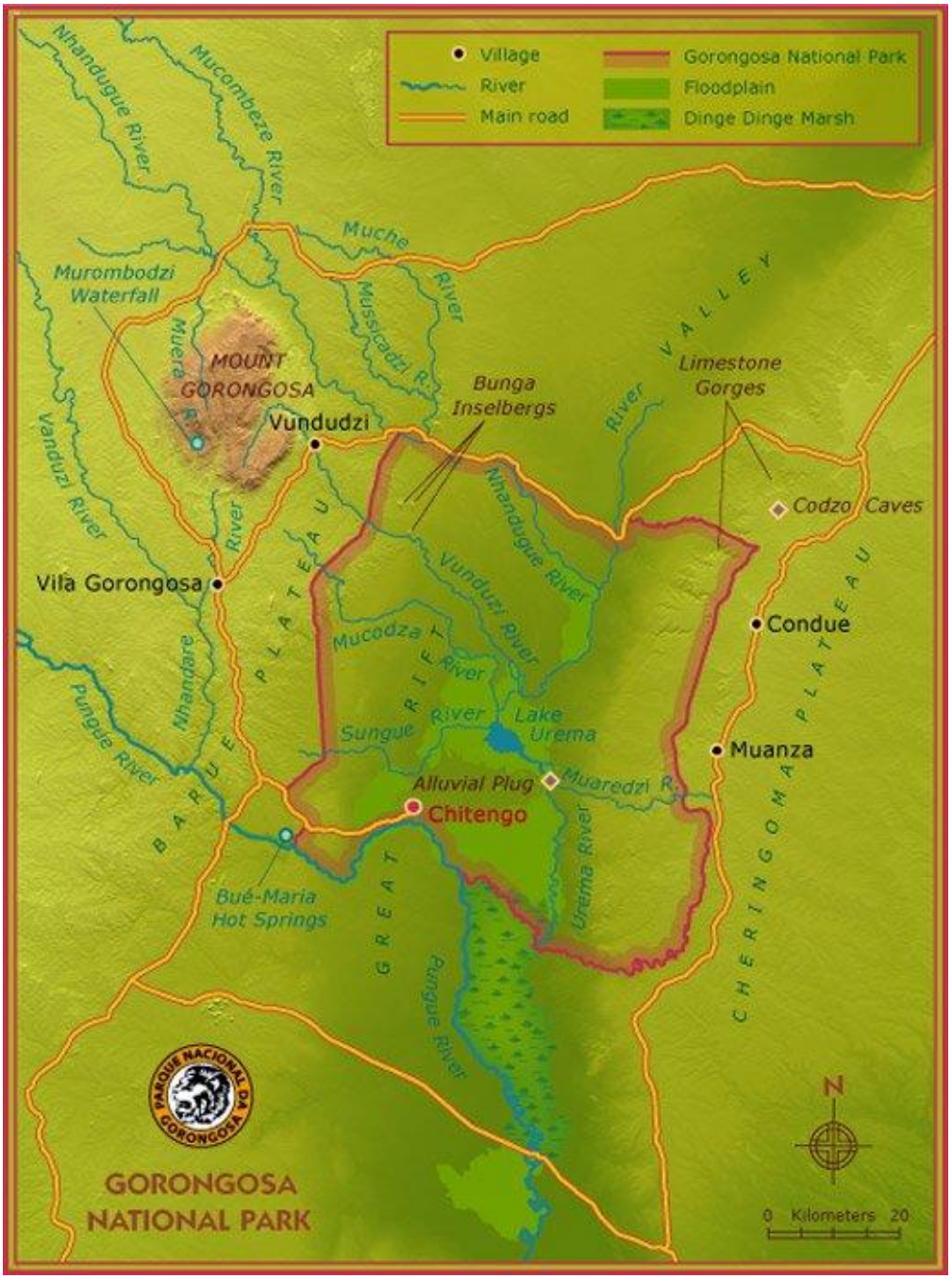


Figure 2: A map of the Greater Gorongosa Ecosystem depicting the various rivers and the boundaries of the Gorongosa National Park and Mount Gorongosa. (Sourced from **http://www.gorongosa.net/en/page/ecology/ecology**).

If this activity continues, it is expected that not only many rare or threatened species, including some endemics, will be lost but that the Vunduzi and Muera rivers will be negatively affected [web 1]. Reasons being is that foliage from *viz.* rainforests, montane grasslands, riverine forests, not only creates conditions that encourages precipitation *via* the process of plant respiration but that the cover provided assist by reducing evaporation and ensures cooler water temperatures that allows the habitation of certain fish species that have a preference for such conditions. Moreover,

vegetation along river banks helps prevent soil erosion which can lead to higher turbidity levels and sedimentation of the bedrock.

Despite existing regulations that prohibits the hunting of wildlife and the cutting down of indigenous trees the management of Gorongosa is working with local people who inhabit the demarcated areas to create a buffer zone of 5 250 km^2 that will surround the borders of the Park (Beilfuss, 2006). Within this zone development is limited and monitored to ensure protection of the forests and watersheds. Some sections of the buffer zone include the entire area of the GM above the 700 m contour line and a riparian corridor of 50 m width flanking each bank along of the Nhandugue, Vunduzi, and Mucoza Rivers between the Gorongosa Mountain and the Park (Beilfuss, 2006). The Government of Moçambique and the Park's management are encouraging inhabitants above the 700 m boundary to relocate to lower reaches were the populace can have access to government sponsored and built health clinics and schools.

Despite the apparent abundance of rivers in the GNP the most important and only perennial source of water is that of the Vunduzi River (Tinley, 1977) and to a lesser extent the Muera River. Besides wildlife, families living on or near the river are dependent on its extraction for potable water, washing, the irrigation of crops and livelihood of livestock. Hence the health of individuals who use water directly from the river are reliant on the river remaining in a pristine condition.

A means to access the health of a water body is by either using conventional methods whereby the presence of contaminants, in the form of heavy metals, traces of agricultural pesticides and herbicides and/or sewage outfall, are measured or by adopting a bio-monitoring approach whereby the health of aquatic organisms are accessed based on the presence and infestation of internal and external parasites or for signs of lesions and deformities, *etc*. The more polluted a system is the more susceptible fish are to infestation by parasites and other illnesses. Hence the bio-monitoring of the Vunduzi River by assessing the parasite fauna found within was considered here.

Aim of the research

To date no study has been done on the composition of the itchyofauna in the Vunduzi River or other rivers in the Park. Little is known about the fish populations in the upper reaches of the mountain because it is difficult to access. Hence the goal of this study was twofold. The first aim was to establish the fish composition in the Vunduzi River system and to establish what effect biotic vs. abiotic factors have on species assemblages. Since the Vunduzi River is vital and a continual source of water for Lake Urema and the GNP as a whole this investigation serves as a baseline study to assist Park authorities with decision-making when considering the impact anthropogenic activities such as deforestation and increased settlements within the proposed buffer zone may have on the system. The approach used here involved the sampling of fishes from 17 distinctive sites over the spectrum of available habitats in the river and to use univariate and multivariate statistical analyses to evaluate site-to-site variance in fish assemblage relative to changes in habitat structure.

The second aim was based on the fact that fish parasitology has not received a great deal of attention in Moçambique and therefore the parasites of numerous fish species have yet to be investigated in this region. This study will therefore contribute to the existing morphological data, geographical distribution and abundance of fish parasites in Moçambique. The relationship between pollution and parasitism and the potential role of parasites as water quality indicators and as a bio-monitoring tool are investigated.

Our objective is descriptive in nature, broadly comparative and designed to detect assemblage patterns rather than provide complete details of habitat use by particular species. Results are based on a short time period and do not address annual or seasonal changes. Furthermore, the health of the system was assessed based on the degree by which parasite fauna were found on fish sampled. The report ends with recommendations for future investigations and to assist Park management in their decisions forward.

For the purpose of this report the two approaches/aims are dealt with separately. The first section focuses on the ichthyofauna composition while the second investigates the presence of fish parasites in the Vunduzi system.

SECTION ONE: Establishing fish assemblages in the Vunduzi River

Introduction.

The natural distribution and assemblages of fish within a system are driven by a number of factors. Primary among these are physical (viz. natural obstacles e.g. waterfalls or man made structures such as wiers or dams) and ecological barriers (e.g. altitude, temperate vs tropical regions, brackish vs freshwater *etc.*). Included in these driving factors are a species' physiological and biological tolerances (the ability to live within a specific range of environmental parameters) and behaviour patterns (e.g. feeding preference, shoaling vs solitary, utilisation of different habitats during the lifecycle e.g. anadromous species such as adult eels, *Anguilla* spp, and trout, *Salmo* and *Oncorhynchus* spp, spawn in the ocean and the young migrate into freshwater systems to mature) (Skelton 2001).

Besides the physical margins of a water body being limiting to distribution, barriers such as waterfalls can prevent a species migration within a system and may divide a fish fauna by isolating groups of individuals above the waterfall whilst others populates the water below. At a physiological level, being poikilothermic, the thermal tolerance of a fish is often a major factor limiting distribution. Southern African freshwater fishes are broadly categorised into temperate and tropical fauna. Fish species tolerant of temperate conditions are restricted to areas where summer temperatures range between 25 - 28°C. Conversely tropical fauna inhabit areas where temperatures during winter do not fall below 15°C for any length of time (Skelton, 2001). Besides daily and seasonal fluctuations in temperature the size and scale of a river system can create a noticeable gradient in temperatures with cooler temperatures recorded at higher altitudes, becoming warmer as the river descends towards the mouth and low lying areas. In such systems, species that have a preference for cooler waters will occupy the upper reaches whilst those with a preference for warmer temperatures will occur further downstream. Another physiological factor is tolerance towards a change in salinity where species are categorised as being either euryhaline and stenohaline. The former being able to tolerate a wide range of salinities and the latter limited to within a specific range.

Another driving factor that governs fish assemblages is the availability of food. Freshwaters are productive environments that provide a wide range of foods. Items such as leaves, seeds and insects that fall become available as external sources of food. Fishes are often opportunistic when feeding

but within a community some species have evolved to become specialised feeders that consume detritus (detritivors) or plankton (filter feeders) whilst others are primarily herbivorous, omnivorous, carnivorous and piscivorous in nature. Hence, depending on the food preference, fish will inhabit certain areas within a system were these food sources are available and abundant.

The production and carrying capacity of a river system is dependent on the water quality that will allow for all levels of the foodweb to function properly. Major causes that have led to the deterioration in freshwater quality are due to landscape changes associated with anthropogenic activities such as mining, urbanization and agriculture practices. Such changes have led to an increase landscape fragmentation, impervious surface area that, in turn, have led to an increase in storm runoff and stream sedimentation, the reduction in groundwater recharge and a loss in riparian habitat. Construction of dams, weirs and/or retention walls for the purpose of water extraction to irrigate agricultural lands, for use by industry and as a result of urban development, obstructs the natural flow of a system. Alternatively the discharge of water used by industry, from urban settlements (sewage) and runoff containing herbicides and pesticides from agricultural lands deteriorates water quality. Provided that the degree of pollution is not above a critical level, most rivers have a considerable capacity for recovery, with contaminates being either dispersed, diluted or degraded. However, when the recovery capacity is exceeded, severe pollution can lead to changes in the biota and losses in fish productivity.

Rain that falls in the catchment area or river basin will eventually find its way into the river as surface or sub-surface flows, carrying with it a variety of dissolved, suspended or particulate matter. Changing conditions within the basin can lead to variations in water quantity or quality, or silt loading that in turn can affect the channel formation. These events can lead to considerable variation in the fluvial environment (Winemiller and Jepsen 1998). Turbidity is caused by the runoff of topsoil originating from agricultural lands or areas where soil erosion occurs. Light penetration is directly related to water clarity and increased turbidity diminishes light infiltration into the water column. A reduction in light not only has a direct effect on the range of sight in fish e.g. in the case of predators that require vision to hunt and fish that display breeding colours (especially cichlids such as breams, tilapias and others) but it also has an effect on aquatic organisms that are dependent on a light source for photosynthesis *viz.*, plants, algae and phytoplankton. Moreover, increased turbidity causes the clogging of gills whereas the settling of fine sediment deposits can blanket the bottom substrate and smother the habitat of benthic organisms. This in turn reduces food available to fish thereby contributing to the decrease in populations. Frequent deposition

(sedimentation) or by contrast scouring (removal of sediment) can change riverbed surfaces which in turn can affect the breeding habitats of certain fish species e.g. *Tilapia rendalli*, that clear nesting depressions in the sediment.

The distribution ranges of many fish species have either increased through translocation and introduction into new areas or have declined due to the destruction of their natural environment and/or as a result of introducing alien fishes for purposes of sport fishing and angling such as largemouth, small mouth and spotted bass (*Micropterus* spp), brown trout (*Salmo trutta*) and the rainbow trout (*Oncorhynchus mykiss*) that displace or predate on native species.

Although fishes are highly mobile creatures they have a tendency to inhabit certain areas within a river based on physiological and biological tolerances and feeding and breeding behaviour. Hence our objective was to detect assemblage patterns of fish in relation to the habitat in which they were caught. In order to do this the following procedures were followed.

Methods

Surveys were conducted between 20th - 24th June 2011 and 14th- 18th October 2012. The fieldwork undertaken during June 2011 was a preliminary study that was done soon after the rainy season whilst sampling in October 2012 was more intensive and done prior to the start of the wet season.

Description of the study area

The physical environment *viz.* bottom substrate, soil patterns, hydrology and riparian vegetation has a direct bearing on the path and flow of a river. A detailed description on the ecology, physiography, geology, hydrology and climate in the Gorongosa National Park and surrounding areas has been done by Tinley (1977) with later work by Böhme *et al.* (2006), Stalmans and Beilfuss (2008) Steinbruch and Merkel (2008) and Arvidsson *et al.* (2011) to, name a few, focusing on various aspects of the ecology, hydrology and/or geology, *etc.* Hence, only the most salient features and their underlining geology and some environmental factors that influences the Vunduzi River will be briefly mentioned here:

- Physiography

As elucidated above the GNP and its surrounding Buffer Zone is comprised of four distinct regions *viz*. the Gorongosa Mountain, Báruè Midlands, Rift Valley and Cheringoma Plateau. The GNP occurs at the southern end of the Great Rift Valley system. The Rift Valley is the salient feature of the area with its 40 km wide low lying valley floor that is situated 15 to 80 meters above sea level (asl). The eastern margin the Rift Valley rises up to 300 m to form the Cheringoma Plateau while the western edge of the Rift Valley is featured by the deeply undulating and incised Báruè Midlands that rises 400 m asl. The Gorongosa Mountain ascends 1400 m above the surrounding Midlands with the highest point of the massif being 1 863 m asl (Stalmans and Beilfuss, 2008).

- Geology and soils

The Gorongosa Mountain is characterised by its cretaceous granitic core that has weathered erosion and penetrated the old basement (Gneiss). Under the influence of the very high rainfall some of the granites weather into ferralitic soils of low fertility. Richer soils are found on the talus that is derived from the weathering of the gabbro and dolerite igneous rocks that occur on the outer rim of the granite core (Stalmans and Beilfuss, 2008).

The Báruè Midlands are mostly underlaid by Precambrian quartzose, feldspatic and micaceous gneisses and pegmatite veins (Lachelt, 2004 cited in Stalmans and Beilfuss, 2008). The area is characterised by many dolerite dykes making the landform undulating and incised. Midland soils are generally nutrient deficient and highly permeable (Böhme, 2005).

The Rift Valley floor is generally characterised by alluvial deposits with colluvial material deposited at the bottom of the Cheringoma Plateau (Figure 3). Sediment deposited at the margin of the Urema Rift floor comprises coarse proximal facies whilst in the central region of the valley fine-grained silts and clays form and are found in interfan slacks and/or basins. These interdistributary features are saturated with calcium, magnesium and sodium and high phosphorous content (Fernandes, 1968 cited in Böhme, 2005). The diversity of deposits on the rift floor is responsible for changes in pH and water salinity (Böhme, 2005). Cherigoma Limestone Formation (Middle –Upper Eocene) underlies the Pleistocene sandy alluvium and Miocene Mazamba Sandstone (Miocene) in the middle section of the valley (Böhme, 2005).

The Cheringoma Plateau consists of grauwackes and limestone. Weathering and eluviation has resulted in the formation of two pedogenic/karst features, namely upper siliceous deposits forming beige pinkish-yellow, orange or deep red (oxisol) permeable sands. The lower unit is much richer in iron oxides and clays forming high water table areas covered in grasslands. Due to a high rainfall in this area the soils are thoroughly leached resulting in surface pH values ranging from 6 to 6.5 (Stalmans and Beilfuss, 2008).

- Climate

The GNP area is influenced by monsoon circulation with a seaward migration of the Intertropical Convergence Zone across Southern Moçambique occurring between December and February. However, the Gorongosa Mountain, Báruè Midlands, the Cheringoma Plateau and the rift valley are different physiographic regions with the floor of the Urema Rift being the driest of all the four regions receiving an annual precipitation of between 600 to 1 000 mm per year (Tinley, 1977), whilst having the highest evaporation of evaporation rate of < 1600 mm per annum. Mount Gorongosa was found to be around 1000 mm per year (Owen, 2004 cited in Böhme, 2005). The mean annual rainfall at Chitengo (the main camp in the Park) is recorded to be 840 mm with an average temperature of 25.7°C (Tinley 1977).

The crest of Cheringoma Plateau experiences on average rainfall of 1 000 – 1 400 mm per annum. As rainfall decreases with an increase in distance from the sea, the Rift Valley to the west lies in the plateaus rain shadow and receives around 700 - 900 mm per annum. However, subject to orographic effects averages in certain areas in this region can rise to 800 – 1 200 mm. Rainfall quickly escalates with an increase in elevation towards Gorongosa Mountain with values in excess of 2 000 mm occurring on the mountain. The area immediately north of the mountain lies in its rainshadow (Stalmans and Beilfuss, 2008).

- Hydrology

The GNP and its Buffer Zone are drained by a multitude of rivers and streams. Drainage occurs from Gorongosa Mountain, the Midlands and the Cheringoma Plateau down into the Rift Valley. Lake Urema is at the epicentre of the drainage with the overflow draining into the Pungue River on its way to the ocean. The extreme eastern part of the Buffer Zone is drained eastwards directly towards the Urema and then into the Pungue River (Stalmans and Beilfuss, 2008).

- Vegetation

Whereas the underlying geological, geomorphological and climatic conditions may be fairly uniform, the landscapes and vegetation can be very distinct due to interactions between the topography, soils and water within a specific region. Since the vegetation of concern here was primarily riparian and aquatic, it was not the purpose of this report to discuss or consider the change in vegetation within the different regions of the Park as Tinley (1977) and Stalmans and Beilfuss (2008) have described this topic in great depth.

- Habitat description of the sampling sites sampled

The source of the Vunduzi River is a small stream approximately > 1500 m asl. The headwaters of the river descends the foothills of the Mountain where it meets the Mecombeze River that flows into Lake Urema, which is nestled in the Urema Valley at an elevation of ≈ 24 m asl Since distinct zones along a river are defined by gradient and the nature of the river bed (Skelton, 2001), prior to sampling, it was decided that the river be divided into three zones which constituted the upper reaches of the river on Gorongosa Mountain (Upper Zone: with sites being sampled above and slightly below the 700 m contour), the intermediate reaches (Middle Zone)and the lower reaches (Lower Zone) being those found within the Park area along the Urema Valley floor.

In the Upper Zone (950 - 600 m) the river descends rapidly flowing over huge boulders and large cobble stones that intermittently gives way to a series of water falls, the largest waterfall having a height in excess of 100 meters. At the base of waterfalls are rock-pools that varying in size and depth. Adjacent the river are forests of hardwood which contributes woody material to the streams. Most sites are heavily shaded. Aquatic macrophytes are absent in this zone. Water is cool and clear as colouration by organic compounds is absent and well oxygenated due to features such as waterfalls, cascades and fast flowing rapids.

Figure 3: A typical scene on the upper reaches of the mountain where large boulders and a narrow channel are prevalent.

In the Middle Zone (600 m - 200 m asl) the riverbed and substrate changes from boulders to a predominantly rocky cobbled channel that is interspersed with small patches of sediment build-up. Once the river reaches an elevation of around 200 m the riverbed becomes gravel. In this zone waterfalls and cascades are less frequent and give way to fast flowing rapids and pools which are larger and shallower. As the river descends further it becomes broader and at times swells to > 30 m in width. Riverine banks are flanked by montane forest and well shaded except where established patches of montane grasses and *Phragmites* have taken root near the river margins. Areas where sediment accumulation has taken place and sections of the river have a sandy bottom, but there is little aquatic vegetation to be found. The water remains clear and is slightly warmer than the upper reaches. There are areas where invasions of exotic mango, avocado, banana and wattle trees can be found. The nature of the riverbed changes to smaller cobbles and pebbles with sandy patches in pools. In some places the river flows through flatter areas where semi-aquatic species like sedges and grasses have been able to grow. There is, however, no submerged vegetation in the stream itself, due to the absence of sediment accumulations. In most places, the river flows in a deeply incised channels with rock bars and boulders in many places.

Figure 4: A common scene from the intermediate region where the river widens and large boulders give way to rocks.

In the Lower Zone (200 – 50 m asl) and on entering the Park boundary the river substrate becomes gravel and sandy with sediment deposition being more extensive. Due to the gentle gradient rapids are less frequent with waterfalls absent and in some areas deep rocky depressions that form pools behind rock bars. The flow rate is comparatively slower to those found in the intermediate and upper zones. Riverine banks are relatively steep and flanked with dense patches of riparian vegetation, the river begins to flow through a wider flat valley plain that is susceptible to flooding. Reeds, *Phragmites mauritianum*, are strongly rooted and found to grow on sandbanks. These plants assist to stabilise the sandbanks and permit the growth of small shrubs, sedges and

Figure 5: Characteristics of the Vunduzi River at the lower reaches where the riverbed is covered in sediment.

grasses. Sections where the current is slow to gentle the riparian vegetation directly shapes the channel by directing the flow around stumps and roots of living trees. As opposed to the densely populated montane forests in the upper reaches most of the river in the lower zone has less cover with Lake Urema being completely void of any shade due to an absence of trees around it periphery and its size. In sections of the river flanked by riparian vegetation the foliage thereof contributes plant material to the streams and river. The occurrence of some aquatic macrophytes can be found in sheltered backwaters.

Figure 6: A photo taken from the Hippo House of Lake Urema along its southern bank.

Sampling procedures

Seventeen stations, 16 along the river and one situated in Lake Urema, were selected (Figures 7 – 24). The first five sites, above 600 m elevation, were chosen on the basis of their stratification (a change in altitude) and selected based on the presence of natural barriers *e.g.* waterfalls, pools, rapids *etc.* For the lower reaches eight sites were selected based on a change in elevation and habitat such as the presence of natural barriers and/or the presence of human activity. The last four sites were confined within the Park's boundaries. Three of the stations sampled (sites 14, 15 and 16) were located approximately half way between Mount Gorongosa and Lake Urema with the last site being in the lake (Figure 7). For the recording of coordinates a handheld GPS (Model: GARMIN *etrex* Legend) was used.

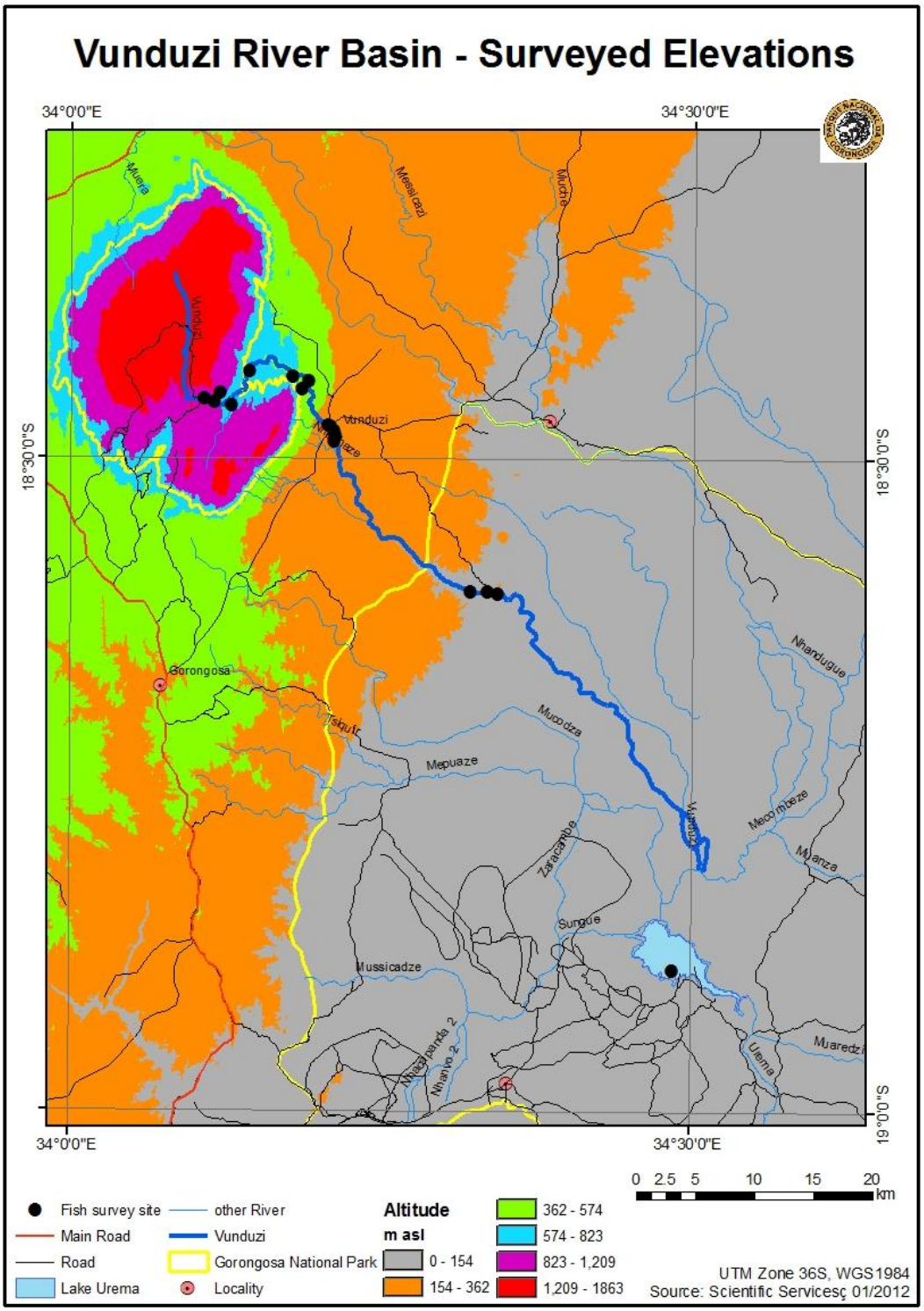


Figure 7: Map indicating the path of Vunduzi River from Mount Gorongosa to where it meets the Mecombeze River in the National Park. The different sampling sites (black circles) in relation to the elevation are shown.

8(a)

8(b)

Site 1: (Figure 8 a, b)

Name: Waterfall

Position: 18° 27’ 21.10” S; 034° 6’ 24.70” E

9(a)

9(b)

Site 2: (Figure 9 a, b, c)

Name: Mwanari

Position: 18° 27’ 30.10” S; 034° 6’ 54.00” E

9(c)

10(a)

Site 3: (Figure 10 a, b)

Name: Fork

Position: 18° 27’ 37.60” S; 034° 7’ 43.20” E

10(b)

11(a)

Site 4: (Figure 11 a, b)

Name: Nkowe

Position: 18° 27’ 4.80” S; 034° 7’ 8.80” E

11(b)

12(a)

Site 5: (Figure 12 a)

Name: Matesso

Position: 18° 26’ 3.30” S; 034° 8’ 33.60” E


13(a)

Site 6: (Figure 13 a, b)
Name: Nhanzore
Position: 18° 26’ 15.70” S; 034° 10’ 40.50” E


13(b)


14(a)

Site 7: (Figure 14 a, b)
Name: Matanda
Position: 18° 26’ 18.00” S; 034° 11’ 4.08” E


14(b)


15(a)

Site 8: (Figure 15 a, b)
Name: Old crossing
Position: 18° 26’ 53.50” S; 034° 11’ 24.60” E


15(b)


16(a)

Site 9: (Figure 16 a, b)
Name: Cara Scareva
Position: 18° 28’ 32.16” S; 034° 12’ 23.40” E


16(b)


17(a)

Site 10: (Figure 17 a, b)
Name: Matanda 2
Position: 18° 28’ 35.52” S; 034° 12’ 29.16” E


17(b)


18(a)

Site 11: (Figure 18 a, b)
Name: Jornal
Position: 18° 28’ 47.46” S; 034° 12’ 39.48” E

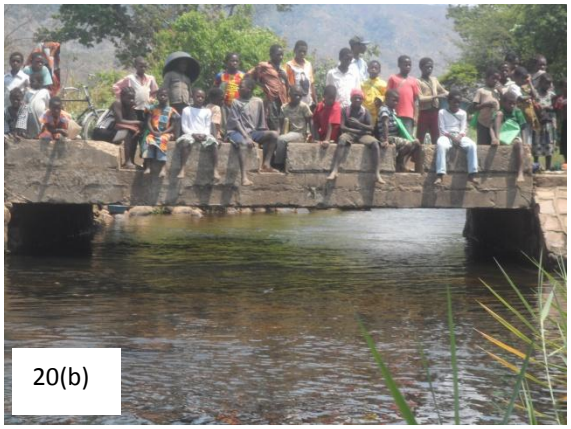

18(b)

19(a)

Site 12: (Figure 19 a)
Name: Jornal 2
Position: 18° 29’ 3.00” S; 034° 12’ 43.26” E

20(a)

Site 13: (Figure 20 a, b)
Name: Village bridge
Position: 18° 29’ 16.20” S; 034° 12’ 39.66” E



20(b)

21(b)

Site 14: (Figure 21 a, b)
Name: Ranger’s site Bunga 1
Position: 18° 36’ 12.10” S; 034° 19’ 16.50” E

21(b)

22(a)

Site 15: (Figure 22 a, b)
Name: Bunga 2
Position: 18° 36’ 10.10” S; 034° 20’ 4.60” E

22(b)

23(a)

Site 16: (Figure 23 a, b)
Name: Bunga 3
Position: 18° 36’ 15.60” S; 034° 20’ 34.60” E

23(b)

24(a)

Site 17: (Figure 24 a, b)
Name: Lake Urema
Position: 18° 53’ 31.50” S; 034° 29’ 5.80” E

24(b)

During the preliminary study three sampling gears were used; a backpack electrofishing unit, a throw net and seine-net having a mesh size of 40 mm. The electro-shocker was found to be the most efficient. During the subsequent trip all specimens collected, except in Lake Urema where a seine net was used, was accomplished with the aid of the electrofishing unit and two netters (Figure 25). At each site, sampling was done for a period of one hour and depending on the outlay of the river the distance covered was limited to approximately 100 m along its length by sampling 50 m up and downstream from the point of entry.

Where possible fish caught that were readily identifiable were examined for external parasites, the caudal and total length measured and recorded to the nearest 1 mm, weighed and then released. For all species caught a representative sample of 5 – 10 fish from each site was set aside in order to examine for internal parasites.

Conversely, specimens not easily identifiable were placed into 10% formalin and later preserved in 70% ethanol and returned to the laboratory for identification. At the laboratory specimens caught were examined for parasitic infections and the size and mass of the fish recorded. For species that were regarded as rare e.g. *Parakneria mossambica*, only two or three individuals were taken for further analysis, with the rest returned. In Lake Urema a seine net 600 m in length with a mesh size of 40 mm was used. Field work on the lake was performed with an inflatable boat powered by a 10 hp outboard motor.

Figure 25: Collecting fishes by means of a backpack electrofisher and the assistance of two netters.

Readings of water parameters were taken at different times of the day. This was unavoidable as sampling at the various sites took place at different times of the day. At each site dissolved oxygen levels, temperature, pH, conductivity and salinity were measured with a handheld YSI multiparameter meter (Model: YSI 556 MPS) while flow rate was established with the use of a flowmeter (Model: PASCO Scientific PS-2000). All measurements were taken at the bottom and near the surface of the water column.

Physical habitat assessment

Habitats were assessed whereby the type of bottom substrate, pool variety, bank stability, light penetration, and riparian zone conditions at stream reaches were scored. The substrate was visually characterised within a 3 m radius from the point of entry into five categories based on the granule size of the sediment such that:

- Silt < 0.05 mm
- Sand 0.5 – 2 mm
- Gravel 2 – 10 mm
- Pebble 10 – 30 mm
- Cobble 30 – 200 mm
- Rock > 200 mm

The percentage substrate coverage at each site was determined. The percentage of aquatic vegetation and percentage riparian cover was also assessed. The stream habitats was categorized according to depth;

- 0 - 5 cm (riffels and margins)
- 5 – 20 cm (riffels and shallow pools)
- 20 – 50 cm (pools)
- > 50 cm deep pools.

The percentage composition of habitat data at all sampled stations is given in Table 1.

Statistical analysis

Based on the data set collected the Shannon-Wiener index was used to test for diversity and evenness between sites. A combination of correlation and multivariate analyses was used to quantify the variation in the altitude, water quality and fish assemblage structure and to identify possible linkages among these attributes. Fish assemblages were analyzed on the basis of species composition.

Patterns in fish assemblage structure among the sites were examined using cluster analysis. The interactions between variables were explored by means of multivariate statistical analysis techniques. Cluster analysis using Ward's minimum variance method was done on the combined dataset containing site descriptors and fish species abundance results for the 17 sampling sites. Confidence of linkages between nodes was established by bootstrapping (N = 10 000).

Results.

Parameters measured at each station are given in Table 1. In this study temperature increased with a decrease in elevation. Similarly the percentage of rock substrate decreased with a decrease in altitude. However, the opposite was true for the percentage composition of silt and sand. The percentage of vegetation remained relatively consistent throughout with riparian cover being dominant for all stations except at Lake Urema where trees and low lying shrubs were absent, with drifting patches of *Eichhornia crassipes* and *Ceratophyllum demersum* dominating the margins. *Azolla nilotica, Trapa natans* and *Pistia stratiotes* were recorded by Böhme (2005) in the lake near the inflow region of the Mucombeze River. No such plants were seen while sampling during this study.

In the upper reaches of the river sampled (stites 1 – 5), the water was found to be soft (conductivity 0.03 – 0.20 $mS.cm^{-1}$), pH circumneutral (pH 6.4 – 7.8) and dissolved oxygen levels high to saturated (5.9 – 10.2 $mg.L^{-1}$), decreasing slightly when descending. Water temperatures increased considerably (17.6 – 21.9°C), with a decrease in elevation. Flowrate was found to vary from 0.1– 0.3 $m.s^{-1}$ while the average depth remained shallow ≈ 0.6 m.

In the intermediate zone (stations 6 – 13) water conductivity increased slightly ranging between 0.03 – 0.25 $mS.cm^{-1}$. The pH remained circumneutral at 6.3 – 7.9. Water temperatures (22.0 – 26.4°C)

increased with a decrease in altitude. The presence of rapids facilitated dissolved oxygen levels in excess of 9.0 $mg.L^{-1}$ only to decrease to 1.9 $mg.L^{-1}$ in areas where the flow rate was > 0.29 $m.s^{-1}$.

In the lower zone (stations 14 – 17) water was more turbid due to siltation. The water became slightly harder at 0.03 – 0.61 $mS.cm^{-1}$ and acidic with pH remaining at a constant 6.5. Water temperatures were higher and remained fairly consistent (26.0 – 27.6°C) across stations. The average depth did not exceed 1.1 m.

A total of 1 257 specimens representing 25 species in 9 families were caught (Table 2). Of the specimens caught *Parakneria mossambica* was found to be indigenous to Gorongosa (Skelton, 2001) whilst *Rhabdalestes mauensis* was found to be outside it distribution range as classified by Skelton (2001). These two species accounted for less than 3.9% of the overall abundance, and were included in the multivariate analyses. The most abundant fish caught was *Barbus bifrenatus* (*N* = 334) followed by *Chiloglanis neumanni* (*N* = 277), *Amphilius uranoscopus* (*N* = 128) and *Labeo cylindricus* (*N* = 116). Of all the species *Amphilius uranoscopus* was most prolific as it was found at 14 of the sites sampled followed by both *Chiloglanis neumanni* and *Labeo cylindricus* which were found at 6 of the 17 stations. Conversely the least, with a single specimen caught, were *Barbus trimaculatus*, *Pharyngochromis acuticeps* and the electric catfish *Malapterurus shirensis*. The most widely dispersed species was found to be the mountain catfish, *Amphilius laticaudatus*, since it was caught at 14 of the 17 stations sampled (Table 1).

In general terms it has been observed that the family Cyprinidae dominates the river fish fauna comprising 56% of all species caught followed by Mochokidae with 24% and Amphiliidae with 10% (Figure 9). The catch per unit effort (CPUE) ($g.h^{-1}$) was found to the highest at site 14 with a biomass of 1 305 g caught, all derived from one species being *Labeo cylindricus* (Table 3). The second highest CPUE of 973 $g.h^{-1}$ was recorded at station 10. The total biomass caught for all 16 sites equated to approximately 5 547 g (Table 3).

The diversity and evenness of species caught were found, in general, to increase the further downstream one sampled (Table 4). Besides having the same number of different species caught (*N* = 13) the highest index recorded was found to be at stations 15 and 16 having indices (Shannon H) of 1.81 and 1.51 and an eveness of 0.61 and 0.35, respectively.

Table 1: The percentage composition of habitat data and physical parameters at all sampled stations.

Parameters		Stations																
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Substrate (%)	Silt	-	-	-	-	-	-	-	10	3	5	-	-	5	-	1	-	64
	Sand	-	5	-	5	-	-	-	20	7	5	40	10	60	10	99	30	35
	Gravel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pebble	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cobble	-	-	5	2	-	-	-	-	-	-	-	-	-	-	-	-	-
	Rock	100	95	95	93	100	100	100	70	90	90	60	90	35	90	0	70	1
Vegetation (%)	Aquatic	-	-	-	-	-	-	-	-	-	-	5	5	-	-	-	-	100
	Riparian	100	100	100	100	100	100	100	100	100	100	95	95	100	100	100	100	0
Physical	Altitude (m)	930	815	770	679	614	435	416	380	285	273	273	270	266	81	64	58	18
	Conductivity ($mS.cm^{-1}$)	0.20	0.10	0.03	0.04	0.09	0.03	0.21	0.25	0.03	0.15	0.08	0.23	0.12	0.05	0.10	0.05	0.06
	DO ($mg.L^{-1}$)	10.2	7.4	5.9	7.1	5.9	9.3	1.9	2.1	1.9	4.2	2.1	2.0	3.1	2.8	2.4	1.9	3.2
	Depth (m)	0.4	0.5	0.5	0.9	0.9	0.8	0.8	0.5	1.0	0.2	0.6	0.5	0.6	0.6	0.4	0.9	1.1
	Flow rate ($m.s^{-1}$)	0.1	0.2	0.1	0.3	0.2	0.6	0.3	0.1	0.1	0.5	0.6	0.4	0.0	0.8	0.2	0.5	0.0
	pH	6.7	7.8	7.2	7.6	6.4	7.2	6.8	7.9	6.8	6.3	6.4	6.5	6.6	6.5	6.5	6.5	6.5
	Temperature (°C)	17.6	18.9	18.8	19.7	21.9	22.0	23.2	24.3	26.4	24.0	25.3	24.6	24.4	27.3	26.1	27.2	27.5

Table 2: The number and species of fish caught at each of the various sites.

Family	Species	Stations																	Total caught per species
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
Malapteruridae	*Malapterurus shirensis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	**1**
Clariidae	*Clarias gariepinus*	-	-	-	-	-	-	-	-	-	-	2	1	2	-	-	-	-	**5**
Amphiliidae	*Amphilius laticaudatus*	10	1	5	15	6	4	4	1	20	46	4	4	1	-	-	1	-	**122**
	Amphilius uranoscopus	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**6**
Mochokidae	*Chiloglanis neumanni*	-	-	-	-	-	-	-	-	1	195	12	1	-	-	1	67	-	**277**
	Chiloglanis pretoriae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	24	-	**26**
Kneriidae	*Parakneria mossambica*	-	-	-	-	-	-	-	-	8	1	26	-	-	-	-	-	-	**35**
Cyprinidae	*Barbus annectens*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	44	-	-	**44**
	Barbus barotseensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	26	-	**30**
	Barbus bifrenatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43	291	-	**334**
	Barbus hassianus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	38	-	-	**38**
	Barbus kerstenii	-	-	-	-	-	-	5	1	-	-	2	18	24	-	-	-	-	**50**
	Barbus lineomaculatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	10	-	**12**
	Barbus radiatus	-	-	-	-	-	-	-	6	-	-	-	-	-	-	9	9	-	**24**
	Barbus trimaculatus	-	-	-	-	-	-	-	-	-	1	-	-	-	-	3	12	-	**16**
	Barbus unitaeniatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27	9	-	**36**
	Labeo cylindricus	-	-	-	-	-	1	-	-	-	7		2	5	28		73	-	**116**
	**Opsaridium zambezense*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	**-**
Mormyridae	*Hippopotamyrus assorgii*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	**1**
	Petrocephalus catostoma	-	-	-	-	-	-	-	-	-	3	-	-	7	-	-	-	-	**10**
Characidae	*Brycinus imberi*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	3	**13**
	Brycinus lateralis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	**2**
	Micralestes acutidens	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	1	-	**8**
	Rhabdalestes maunensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	-	-	**13**
	**Hydrocynus vittatus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	**-**
Cichlidae	*Chetia flaviventris*	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	**6**
	Oreochromis mossambicus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28	**28**
	Pharyngochromis acuticeps	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	**1**
	Tilapia rendalli	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	**4**
Total caught per station		**16**	**1**	**5**	**15**	**6**	**5**	**9**	**15**	**29**	**253**	**46**	**26**	**45**	**28**	**200**	**526**	**32**	**1258**

*Indicates species caught during the preliminary sample but not included for analysis

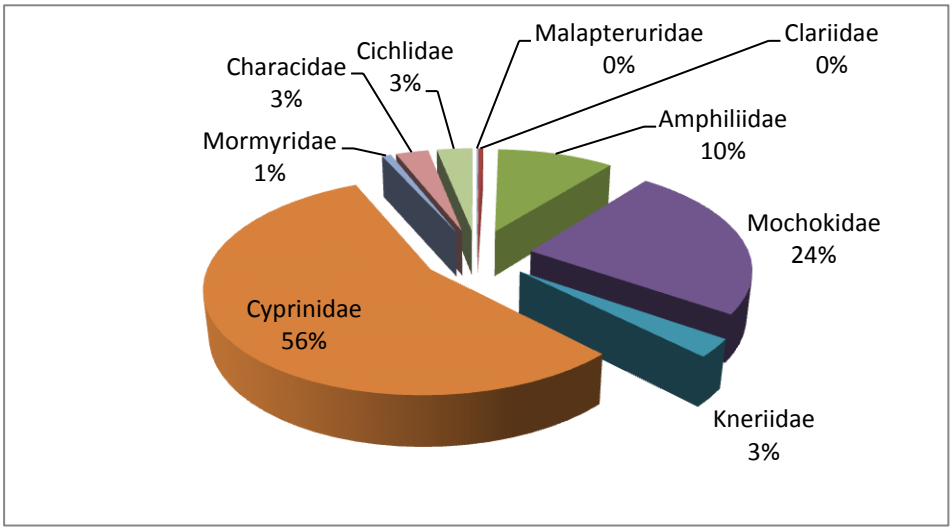


Figure 26: A pie diagram indicating the percentage dominance in numbers of fish families caught in the Vunduzi River over the sampling period from 14 - 18th October 2011.

By using cluster analysis, results revealed the presence of three distinct clusters (100% retention of primary node after bootstrap). Cluster A contained sites 1 to 5, while clusters B and C contained the remainder of the sites (sites 6 to 13 vs sites 14 to 17), albeit the confidence of this node was moderate with a 64% retention after bootstrapping (Figure 10).

Table 3: The biomass (g) of fish caught at stations 1 - 16.

Family	Species	Stations																Total biomass per species
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Clariidae	*Clarias gariepinus*	-	-	-	-	-	-	-	-	-	-	340	50	260	-	-	-	**650**
Amphiliidae	*Amphilius laticaudatus*	71.2	2.6	13.7	20	10.4	4.6	6.3	2.5	40.7	139.5	9.4	15.5	3.2	-	-	0.53	**340.13**
	Amphilius uranoscopus	12.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**12.1**
Mochokidae	*Chiloglanis neumanni*	-	-	-	-	-	-	-	-	2.3	311.9	36.5	3.7	-	-	0.24	24.49	**379.13**
	Chiloglanis pretoriae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.33	5.44	**5.77**
Kneriidae	*Parakneria mossambica*	-	-	-	-	-	-	-	-	16.7	1	53	-	-	-	-	-	**70.7**
Cyprinidae	*Barbus annectens*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.35	-	**6.35**
	Barbus barotseensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.25	**5.25**
	Barbus bifrenatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11.11	77.47	**88.58**
	Barbus hassianus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.78	-	**3.78**
	Barbus kerstenii	-	-	-	-	-	-	8.5	1	-	-	7.9	31.1	44		-	-	**92.5**
	Barbus lineomaculatus	-	-	-	-	-	-	-		-	-	-	-	-	-	-	2.22	**2.22**
	Barbus radiatus	-	-	-	-	-	-	-	6.7	-	-	-	-	-	-	7.91	6.56	**21.17**
	Barbus trimaculatus	-	-	-	-	-	-	-	-	-	0.4	-	-	-	-	7.73	13.57	**21.7**
	Barbus unitaeniatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.35	**1.35**
	Labeo cylindricus	-	-	-	-	-	33.7	-	-	-	498	-	70.5	46.2	1305.1	-	158.46	**2111.96**
Mormyridae	*Hippopotamyrus assorgii*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.5	-	**1.5**
	Petrocephalus catostoma	-	-	-	-	-	-	-	-	-	22.5	-	-	30.8	-	-	-	**53.3**
Characidae	*Brycinus imberi*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	189.3	-	**254.71**
	Brycinus lateralis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.78	**3.78**
	Micralestes acutidens	-	-	-	-	-	-	-	11.6	-	-	-	-	-	-	-	1.21	**12.81**
	Rhabdalestes maunensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.5	-	**5.5**
Cichlidae	*Chetia flaviventris*	-	-	-	-	-	-	-	-	-	-	-	-	31.2	-	-	-	**31.2**
	Pharyngochromis acuticeps	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.75	**1.75**
	Tilapia rendalli	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21.5	-	**21.5**
Total mass (g) caught per station		**83.3**	**2.6**	**13.7**	**20**	**10.4**	**38.3**	**14.8**	**21.8**	**59.7**	**973.3**	**446.8**	**170.8**	**415.4**	**1305.1**	**255.25**	**302.08**	**5548.74**

Table 4: Various indices used to test for species diversity between the different stations.

Site	Number of		Indices				
	Taxa	**Individuals**	Dominance	**Shannon H**	Simpson	**Evenness**	Equitability
1	1	16	1.00	0.00	0.00	1.00	0.00
2	1	1	1.00	0.00	0.00	1.00	0.00
3	1	5	1.00	0.00	0.00	1.00	0.00
4	1	15	1.00	0.00	0.00	1.00	0.00
5	1	6	1.00	0.00	0.00	1.00	0.00
6	2	5	0.68	0.50	0.32	0.82	0.72
7	2	9	0.51	0.69	0.49	0.99	0.99
8	4	15	0.39	1.08	0.61	0.74	0.78
9	3	29	0.55	0.73	0.45	0.69	0.66
10	6	253	0.63	0.71	0.37	0.34	0.39
11	5	46	0.40	1.16	0.60	0.64	0.72
12	5	26	0.51	0.99	0.49	0.54	0.62
13	6	45	0.34	1.36	0.66	0.65	0.76
14	1	28	1.00	0.00	0.00	1.00	0.00
15	10	200	0.20	1.81	0.80	0.61	0.79
16	13	526	0.35	1.51	0.65	0.35	0.59
17	3	32	0.78	0.45	0.22	0.52	0.41

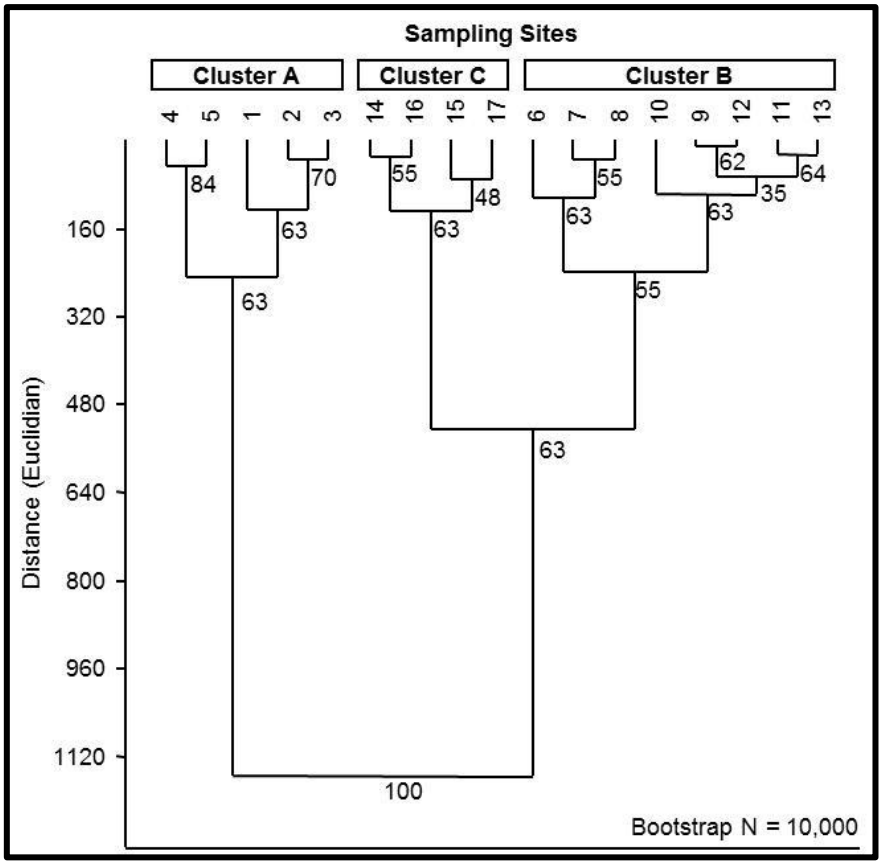


Figure 27: Dendrogram showing cluster analysis (Ward's method) results of site, water quality, and faunal descriptors. Distance measure is squared Euclidian and the distance between two clusters is the ANOVA sum of squares between the two clusters added up over all the variables; bootstrap N = 10 000 (percentage of nodes supported after resampling 10 000 times is given at each node).

Discussion

The Vunduzi River descends from it source down steep slopes where at the foothills of the mountain it crosses the midlands to drain into Lake Urema. Due to the size and height of Gorongosa Mountain a temperature gradient exists with cooler water temperatures found at higher elevations becoming warmer at lower altitudes. In this study a temperature of 17.9°C was recorded at the highest point of sampling that gradually increased when descending along the profile of the river to 27.5°C at Lake Urema. A possible cause for the very low conductivity recorded in the upper reaches could be due to the underlying surface layers of the granite bedrock that over time, due to high water action from orographic rainfalls, have become highly leached and as a result yield little in the way of dissolved ions. Conversely the amount of suspended ions, which were found to decrease as the river drains towards the valley, may be sufficient to act as a buffer system and may be the reason for the water being slightly alkaline in the upper reaches when compared to the lower zones. Temperature and the solubility of oxygen in water are inversely related with colder temperatures yielding higher retention of oxygen levels. Hence due to cooler water temperatures in the upper zone oxygen levels were found to be, on average, higher than those in the subsequent zones. Another factor contributing towards increased oxygen levels was the nature to the river bed whereby the action of waterfalls, cascades and fast flowing rapids allowed the churning of the medium to come into contact with the atmosphere. The particular subset of sites chosen for the upper zone covered a larger range of variation and was considered to be chemically and physically heterogeneous.

Similarly for the intermediate and lower zone, the range of variation covered was considered to be chemically and physically heterogeneous. These zones were characterised by a slow flowing current that flowed through sandbanks and deep (> 2m) stagnant pools situated behind rock bars. Stagnant pools were green in colour and thought to contain *Cynobacterium* spp. Except at site 16 where an aquatic fern was found there was little to no aquatic plants present at the other stations. A reason for the lack of aquatic plants within this zone could be that the magnitude of river flow is strongly seasonal and at times of high rainfall the river bed is scoured of any loose material thereby preventing the roots of slow growing plants the opportunity to become firmly anchored. Alternatively the river in this region could be deficient in nutrients that allow for the facilitation and proliferation of aquatic plants. A constant pH across stations 14 - 17 could be due to sandy alluvium deposits and the underlying limestone in this region that act as buffer when free ions leach from the substrate into the water. It can be inferred that during periods of high water flow the pH will become neutral or moderately alkaline. As opposed to the upper reaches the stations chosen here

covered a much narrower range of variation in water parameters and may be considered chemically and physically homogeneous with all sites sampled being found to be slightly acidic. In order to describe in detail the various zones and habitats where assemblages of fish occur it is required that future studies measure the metal and ion content of the various geological regions over which the river flows.

Figure 28: Aquatic fern found at site 16.

While most of the fish fauna caught in Vunduzi is well known, there is little detailed information on their distribution, biology or habitat preferences. A single species, the mountain catfish *Amphilius laticaudatus*, dominated the upper reaches. The morphology of this fish and that of *Amphilius uranoscopus* is well adapted for living in turbulent waters since, like freshwater eels and sucker mouths (*Chiloglanis* spp), this species can overcome barriers that are difficult to transcend by clinging onto the submerged surfaces using their mouths and by climbing wet surfaces with their pectoral fins. Although greater numbers were caught at site 1, it would seem that this species can tolerate higher temperatures since a single specimen was caught at site 13 in waters of 24.4°C. Although it was not done in the study, sampling above the waterfall to the source of the river might reveal if *Amphillius* spp. and possibly any other species of fish are found in this section of the river.

Future sampling in the upper reaches of the Vunduzi and Meura River may encounter specimens of the long-finned eel *Anguilla mossambica*, the African mottled eel *A. bengalensis labiata* and the giant mottled eel *A. marmorata*. However, although known to migrate hundreds of kilometres inland, such encounters are likely to be rare as they are strongly reliant on the elvers of these species migrating upstream from the freshwater interface of the Pungwe River into the Urema River and lake wherein they can swim further upstream.

The fish fauna in the intermediate zone is more diverse than that of the upper reaches, with 11 species caught therein. All are typical warm water species that are adapted to living in seasonal rivers and include well-known forms such as knerri and mormyrid species, characids, clarids and cichlids. In terms of the number of species, and in terms of relative abundance, the Cyprinidae is the dominant family. There is a considerable diversity of cyprinids with nine *Barbus* species and one Labeo species being the redeye labeo, *Labeo cylindricus*. The latter species prefers clear running waters in rocky habitats and are strong swimmers capable of migrating upstream against strong currents in order to breed. In turbulent water this species is able to use their mouths and broad pectoral fins to scale damp barrier surfaces such as rocks and weirs (Skelton, 2001). The species is widely distributed from East African rivers, as far north as the Zambian and Congo basin, southwards through the Zambezi system and east coastal drainage to the Phongola system in northern KwaZulu-Natal, South Africa.

On the other hand *Barbus* species, or minnows, commonly shoal in large numbers in streams and freshwater bodies. Besides having various distinctive markings in the form of spots and/or stripes their natural colours camouflaged them well against their surroundings with males of most species displaying bright colours during breeding. In general minnows are opportunistic feeders and will ingest items such as diatoms or detritus. They in turn are a nutritional source of food for larger fish and bird predators (Skelton, 2001). In this zone the most dominant barb was *Barbus kerstenii* and occurred in relative high numbers at station 12 (*N* = 18) and 13 (*N* = 24). It grows up to 7.5 cm in size. This species has a narrow geographical rage. The species is found along vegetated fringes of rivers and streams (Skelton, 2001) and due to the description of the habitat at both sites they may have a preference for areas laden with sand. Little is known about the biology and ecology of this species. *B. trimaculatus* was the only spiny finned barb collected during this survey. It grows up to a length of 14.00 cm and is therefore one of the larger barbs collected. *Barbus trimaculatus* is a cosmopolitan species that is hardy with a very wide geographical range. Like most barbs, it does not do well in dams. Very little is known about the ecology and biology of *B. trimaculatus*.

B. annectens, B. barotseensis, B. lineomaculatus, B. unitaeniatus, B. bifrenatus, B. radiatus and *B. haasianus* are all soft-rayed barbs. *Barbus unitaeniatus* is the larger of these barbs and can grow up to 14 cm in length. It is also widely distributed. *Barbus haasianus* is a small barb and only grows up to 3.2 cm and has a narrow geographical range in Mozambique. All the soft rayed barbs are poorly adapted to lacustrine conditions. The biology and ecology of all these barbs is poorly understood.

The barbs are of limited value in the fishing industry. However, a number of barbs identified in this survey could be important in the ornamental fish industry.

The minnows *Barbus toppini*, *B. eutaenia*, *B. afrohamiltoni*, *B. viviparous* and specifically *B. maicensis* which are indicated by Skelton (2001) to be endemic to this area were not caught when sampling. However, *B. unitaeniatus* and *B. bifrenatus* where caught and found to be outside their distribution range as indicated by Skelton (2001). Further confirmation is required in order to reclassify the distribution of these species.

In the intermediate zone there is one truly indigenous species to this area which is the Gorongosa kneria, *Parakneria mossambica*. This species belongs to a group of fish that typically lives in clear, running water and has only been collected in the streams draining Gorongosa Mountain. Little is known about its distribution, biology and population size. *P. mossambica* has a very limited geographical range as it is only found in the streams around Gorongaza. This species may be vulnerable to any habitat changes. A related species in South Africa, *Kneria auriculata* is threatened by habitat destruction and introduction of alien species. The biology and ecology of *P. mossambicus* is not documented. This species could also be an important indicator species. Hence based on available literature and our findings, the Gorongosa Mountain ecosystem is unique as it would seem to be the only region that provides a suitable habitat for this species. Based on our sampling it would seem that this species localises a small region of the river that spans stations 8 – 10 at an altitude of 273 –380 m. Of concern is that the authors were told that local fishermen apply a poison, toxic only to fish, which is extracted from an indigenous plant and which is applied to this region of the river in order to catch fish. Although it can be assumed that these species are not specifically targeted, the extent and frequency to which this practice is done is not known and hence requires further investigation.

The catfish *Clarias gariepinus* was found at the lower reaches of the intermediate zone at stations neighbouring the Vunduzi village. Although this species is found to occur in almost any habitat (Skelton, 2001) they seemed to have localised part of the river where the presence of human activity is large e.g. bathing and the washing of clothes, cookware and eating utensils and where grains such as sorghum and maize are washed, soaked and rinsed in preparation for cooking. Fish at these stations are considered to be opportunistic by feeding on food particles wiped off utensils when washing and on grains that spill over into the river.

Chiloglanis neumanni is widely distributed throughout the Zambezi basin as well as the Pungwe and Buzi rivers. It is a benthic species that inhabits rocky riffles and rapids with fast flowing water. Its buccal sucker enables it to adapt to these conditions (Skelton, 1993). *C. neumanni*'s distribution in Southern Africa is threatened in many countries owing to the construction of dams. This makes it vulnerable to drought because it will not be able to recolonise sections above dams if they dry out completely. The species is therefore considered to be vulnerable if its habitat deterioration occurs in the Vunduzi River. It is suggested that *C. neumanni* be used as an indicator species.

The northern Churchill, *Petrocephalus catostoma*, was found to occur only in the intermediate zone at stations 10 and 13. Indigenous and endemic to this area these species prefer to shoal in the quiet reaches of the river and floodplains. This species breeds during the rainy season and is thought to move upstream to pair (Skelton, 2001). The biology and ecology of this species is not known.

The Characidae, *Micralestes acutidens* is widely distributed and shoals in clear, flowing or standing open waters. The species is omnivorous and often feeds on winged insects that land on the water surface and on zooplankton (Skelton. 2001). In the upper Zambezi River it is one of the few small fishes to remain in the river throughout the year (Bell-Cross, 1974; Van Der Waal, 1996).

The fish fauna in the lower/valley zone is more diverse than that of the upper two zones, with 20 species occurring therein. However, in this zone the diversity of cichlid fishes is relatively low, with only three species recorded. They also occur in relatively small numbers except in Lake Urema where *Oreochromis mossambicus* dominated the catch. The other two species are less numerous but could be expected to occur anywhere in this section of the river. The Zambezi river bream *Pharyngochromis acuticeps* occurs in the upper Save-Runde system in Zimbabwe and is found in a wide range of habitats and finds cover under plant and tree roots (Skelton, 2001). The red breasted tilapia, *Tilapia rendalli* is very wide spread having a distribution covering most of the northern and eastern region of southern Africa. The biology and ecology of this species is well known. The fish prefers to inhabit warm slow moving waters and being primarily herbivorous prefers feeding on submerged vegetation and, at times, on algae, detritus, aquatic invertebrates and small fish. Breeding pairs inhabit shallow areas of the river where they make nests in the sandy substrate containing brood chambers to protect the eggs and larvae (Skelton, 2001). The tilapia species, *O. mossambicus* and *T. rendalli* are of commercial importance. They are pre-adapted to lacustrine conditions and are expected to contribute significantly to the fishery of Lake Urema.

Unique to this zone is the slender robber, *Rhabdalestes maunensis*, as the species has been indicated by Skelton (2001) to occupy the Cunene, Okavango, upper Zambezi and Kafue systems, with its distribution limited to the western and northern regions of southern Africa. With it being found at site 15 our findings would therefore indicate that this species ranges further east of its documented distribution. The fish shoals in shallow, vegetated marginal and floodplain habitats. The presence of multicuspid teeth is an indication that this species is carnivorous in nature. The region of the river wherein this species occur matches habitat criteria requirements described by Skelton (2001). Little is known about the biology and ecology of this species. In the upper Zambezi it remains on the floodplain (Van der Waal, 1996) and it is a shoaling species that leaves amongst vegetation in shallow waters in rivers and floodplains.

Brycinus imberi was caught in the lake. This species has a wide geographical range. It is generally quite numerous wherever it occurs but is not well adapted to lakes (Kenmuir, 1976). In Lake Kariba, *B. imberi* is largely restricted to rivers and river mouths (Bowmaker, 1973). Its numbers are probably influenced by river flow since it is strongly potamodromous (Bowmaker, 1973) and breeding may fail in drought years. *B. imberi* are too small to be of much interest to anglers. They are however caught by subsistence fishermen.

The electric catfish, *Malapterurus shirensis* was also caught from the lake. It lives among rocks or roots and favours standing or slow moving water. Its breeding biology is poorly known and some old reports suggest it may be a mouth brooder because of relatively large eggs. Breder and Rosen (1966) did not accept this claim. Subsistence fisherman catch it within its geographical range. Anglers occasionally catch it, although few do so deliberately since it is a dangerous and unpleasant fish to handle.

The barbed minnow, *Opsaridium zambezense*, was caught at station 16 during the preliminary survey. Its range extends from the upper Kasai, a tributary of the Congo, through to the Okavango, Zambezi, Pungwe and Buzi rivers. This species is not adapted to dams (Kadye and Moyo, 2007). It is mostly found in clear waters of strong flowing rivers and is especially common in rocky areas where it leaves in shoals. The construction of large dams on most major rivers and the spread of exotic predators have adversely affected its distribution and abundance in Zimbabwe (Kadye and Moyo, 2007). *Opsaridium zambezense* is generally absent from polluted streams (Gratwick and Marshall, 2001). The loss of habitat through siltation and reduced river flows is a further threat to this species. *O. zambezense* can be an important indicator species.

Hydrocynus vittatus was also caught at station 16 during the preliminary survey. The tigerfish has a very wide distribution as it occurs throughout much of sub-Saharan Africa. Tigerfish are strongly potamodromatic and move up flowing rivers to breed (Bowmaker, 1973). Their breeding behaviour and spawning sites are unknown but they clearly breed in rivers and the fry move downstream as they get older. There is some circumstantial evidence from Lake Kariba that severe drought affect their breeding. In 1973, there was a marked decrease in the catch of young tigerfish after the 1971/1972 drought (Langerman, 1984). Tigerfish is a premier game fish and highly prized by anglers. Because tigerfish have to go up rivers to breed, they are vulnerable to fishing during their spawning runs. The fish species is also threatened by dam construction and pollution (Skelton, 2001). The tigerfish is potentially an important indicator species.

Despite only three fish species being caught in the Lake Urema when sampling, Böhme (2006) identifies the following species in his work in the lake which are; the sharptooth catfish (*Clararius gariepinus*), the banded tilapia (*Tilapia sparrmanii*), redeye labeo (*Labeo cylindricus*), rock catfish (*Austroglanis sclateri*), tigerfish (*Hydrocynus vittatus*) and the cornish jack (*Mormyrops anguilloides*).

In future fish species characteristic of floodplains such as the lungfish *Protopterus annectens,* the climbing perches *Microctenopoma intermedium*, *Ctenopoma multispin* and others that include some typical east coast barbs (*Barbus viviparus, B. toppini* and *B. macrotaenia*), and a barb that otherwise occurs in the upper Zambezi floodplain (*B. haasianus*) may be found when the plains flood in the lower reaches. Work by SWECO and Associates (2004) states that a large number of marine species enter into the brackish waters of the lower reaches of the Pungwe system and with the exception of three goby species (*Awaous aeneofuscus, Glossogobius giuris* and *G. callidus*) that are known to penetrate up to 1 200 km inland in some systems, few migrate far upstream. Hence it may be possible when sampling sand banks in the lower reaches of the Vunduzi River using a seine-net that these species may be expected.

During the study by SWECO and Associates (2004) specimens caught in upland tributaries of the Pungwe drainage system e.g. the Natal mountain catfish (*Amphilius natalensi*), the rock catfish (*Chiloglanis emarginatus*), the southern kneria, (*Kneria auriculata*), which occurred in the headwaters of the Pungwe, the yellow barb, (*Barbus manicensis*) caught in some numbers in the Pungwe river and the nkupe and chessa, *Distichodus mossambicus* and *D. schenga*, respectively were not found during the present sampling survey..

Cluster Analysis (CA) revealed two main clusters, with the second cluster containing two clearly discernible clusters. Cluster C exhibited the most variation (large convex hull) and this was caused by the relative large number of individuals and taxa observed in the low altitude sample points as opposed to the high altitude sample points (cluster A and B). Species diversity decreased with altitude.

The fish species collected at each station during this survey reflected the physical and chemical conditions of the river that they are adapted for physiologically and morphologically. The morphological adaptations to swift flow of species collected during this study include enlarged and stiffened pectoral spines of *Amphilius spp,* buccal suckers of *Labeo spp* and *Chiloganis spp* and the elongated body forms of *Barbus spp*. Small size is an important adaptation for fast flowing waters. However, the small size imposes limits of trophic specialisation, life span and reproductive capacity. Consequently, a change in the environmental conditions that directly affect the life history patterns of these species will have a negative impact on the diversity and abundance of the small species.
It is concluded that the distribution and abundance of species on the Vunduzi River is related to the longitudinal gradient imposed by decreasing altitude. The number of species increases downstream and the species exhibit adaptations to the fast flowing conditions of the stream.

Fisheries in Vunduzi River and Lake Urema

People catch fish along the entire Vunduzi River system but there are no records indicating the quantity of fish caught, or their importance to local communities. The fishing gear that is used include gill nets, traps and rod and line, as in other parts of the region. It is likely that all fish species are utilised, with a preference for certain species. Some of the larger and more popular fish, such as the tilapias, are known to be sold in local markets or to travellers along the main roads (Böhme, 2006). During Böhme's (2005) study on Lake Urema temporary camps of fisherman were encountered comprising four teams of two fishermen which were from a nearby village Muaredzi, situated some 30km from the lake. After successful catches they returned to the village to sell their catch. Gutted and smoked fish is also sold in Muanza but mainly to a market in Beira and Mafambisse. Fish is caught with the use of nets and spears from dugout canoes. Over the years there has been no data recorded on the number and species caught.

Previously the fishermen were permitted to fish on Lake Urema unregulated. However, there are plans by management to move the fishermen to an area outside the Park where they will be taught how to farm in an attempt to limit fishing on the lake and make the local population neighbouring the Park in that area independent of fishing as means for a livelihood and a source of food. Being a protected area management's plans is to halt fishing altogether in the lake or to allow limited and regulated fishing to take place.

Management and Conservation Issues

Human activities are perhaps the most important agent of change within a river system. This section addresses the impact that such activities might have on the Vunduzi River.

- Changes in water quality

There seems to be little evidence of pollution in the Vunduzi River basin, although there may be some localised sites below the towns and villages. It is unlikely that there have been any significant changes in water quality. Nevertheless, the authorities should make every effort to monitor the situation and attempt to control pollution early before it becomes a serious, and expensive problem.

Agriculture

Proper conservation on Mount Gororngosa will help to maintain the ecological integrity and productivity in the river. Unfortunately this mountain is under immediate threat. Long protected by traditional taboos and political events, the mountain ecosystem now suffers from increasing human influence. The use of land on and around Gorongosa Mountain has, until recently, been happening gradually without apparent effect. It is quite clear that the main objective of land clearing on and around the Gorongosa Mountain is from agricultural production. In particular, on the higher slopes of the mountain, potato production is the crop of choice, serving as both a crop well suited to the slightly cooler conditions of the mountain and as diversification of income. Other crops include the standards corn, beans, pumpkin and sweet-potato.

It is expected that the production volume on the mountain is not significantly different from the surrounding foothills. There is no knowledge on the effect of vegetation clearance on the Vunduzi flow regime because of the absence of long-term data. It is, however, reasonable to assume that flow patterns may have changed and that more silt has been generated and transported down the

river. The effects of this are unknown and will require further investigation. Notwithstanding, some effort should be made to institute adequate management of forest resources to ensure that changes to the river and its fish populations can be controlled.

Forestry

Forests tend to conserve water, soil and nutrients and therefore have a conservative influence on downstream river systems. The clearing of forests has immediate visible impacts on the flow regime of streams, associated with changes in water yield, the timing and duration of runoff, and the generation of silt. Other changes include an increased loss of nutrients, changes in water temperature and pH, and other less obvious impacts. Deforestation of catchments tends to alter the flood characteristics of the system. Flood peaks are accentuated, and tend to be shorter in duration as rainfall is almost immediately converted to runoff. As the vegetation is lost and the topsoil disappears through erosion, there is nothing to delay the movement of water down the slope. Consequently, the flood regime becomes more spiky and unpredictable and the dry season flows are reduced. This can affect fish species, which require a more regular transition between floods and dry periods. During both fieldtrips the clearing of plots by means of fire was evident. The deterioration of riparian habitats have been associated with the decline in native fish, amphibian and aquatic invertebrate assemblages (Dodd and Smith 2003). When the channel gradient decreases, so does the current velocity resulting in the deposition of silt. This provides an anchorage for plants e.g. *Phragmites* spp. which facilitates the blockage of small streams and results in new channels developing. Deeper pools in the river, and lagoons on the floodplain, which provide refuge to many species during the dry season may be filled in with sediment, thus contributing to a reduction in productivity

Conclusion

The Vunduzi River flows through a high erosion area because of the very steep slopes. Clearing of vegetation in this area enhances soil erosion which may lead to siltation of the river. The fish species that will be most vulnerable to poor water quality are:

- *Parakneria mossambica*
- *Amphilius laticaudatus*
- *Amphilius uranoscopus*
- *Chiloglanis neumanni*

- *Opsaridium zambezense*
- *Barbus hassianus*
- *Hydrocynus vittatus*

This study established the habitat preferences of these species but their biology and ecology is poorly understood. Data on the population dynamics of these species is a necessary prerequisite for the development of a conservation framework for these species. These species can also be used as indicators for ecosystem integrity of the Vunduzi River.

SECTION Two: Establishing the parasite fauna in the Vunduzi River

Introduction

The ecological health of an aquatic ecosystem is influenced by a multitude of factors including the geomorphology and geological formations of the region, the chemical and physical quality of the water, the hydrological regimes and the nature of the riparian habitats. Any unnaturally high concentration of contaminants entering an aquatic ecosystem may pose a direct threat to the health of the system and all the organisms living in it. However, every aquatic ecosystem has some natural buffering capacity. The latter allows the ecosystem to adapt to and compensate for natural changes in the environment such as leaching from the soil or the occasional heavy rain. Water pollution occurs when conditions exceed the aquatic ecosystem's ability to compensate for these changes (Dallas *et al*., 1998).

To monitor contaminants in aquatic ecosystems, several approaches can be followed. Chemical analysis and measuring physical variables of water give very accurate measures of the amounts of individual substances in the water but are expensive and only accurate at the time of sampling. Biological monitoring, on the other hand, provides a bigger picture of both the past and the present conditions in an aquatic ecosystem. This is because the organisms that are living in the ecosystem must have been able to survive whatever conditions the system has been subjected to in the recent past (Davies & Day, 1998) and the integrity or health of the biota provides a direct and integrated measure of the health of the ecosystem as a whole.

Biomonitoring

Aquatic biomonitoring is the science of inferring the ecological condition of a water body by examining the organisms that live there (Rosenberg & Resh, 1993). Water quality monitoring has traditionally focused on measuring physical and chemical variables (Roux *et al*., 1993). It is increasingly realized that biological communities in aquatic ecosystems incorporate all of the environmental stresses caused by human and natural activities over a prolonged period. Biological communities may be the only practical means of evaluating certain impacts, which are difficult to measure, for instance diffuse impacts, invasive species, or habitat degradation (Roux *et al*., 1993). When biomonitoring data are used in combination with chemical data, considerably more insight is gained into the link between biological data, water chemistry and aquatic ecosystem health.

Organisms in aquatic environments are considered biologically sensitive and respond to changes that occur in the water. The biotic integrity of an ecological system is therefore reflected in the health of its fauna. Changes occurring in fish populations due to chemical stress are manifestations of biochemical, histological and physical alterations, and can give a relatively rapid indication of how environmental conditions affect fish populations. Fish health may thus reflect, and give a good indication of the health status of a specific aquatic ecosystem.

Fish parasites as Biomonitoring tool

The fact that all free-living organisms are hosts to parasites, and parasitism, in its broadest sense, is considered to be the most common lifestyle on earth (Price, 1980), means healthy ecosystems can hardly be considered parasite free. Each parasite species reflects the presence of different organisms that participate in its life cycle. Together all these parasite species in a host reflect the presence of a plethora of host organisms and trophic interactions in the environment (Marcogliese, 2003). Hence, parasites can be extremely valuable information units about environmental conditions, because their presence or absence tells a great deal about not only their host ecology but food web interactions, biodiversity and environmental stress (Marcogliese, 2003). Combining different species based on shared patterns of transmission provides a potentially more powerful indicator of prevailing environmental conditions (Marcogliese, 2005).

Pollution has a immense effect on the health of vertebrates such as fish, and we can only start to imagine the effect it has on the more sensitive invertebrates that ocupies these aquatic habitats. The relationship between environmental pollution and parasitism in aquatic organisms and the potential

role of parasites as water quality indicators have received increasing attention during the past two decades (Galli *et al*., 2001; Pietrock & Marcogliese, 2003; Sures, 2004). Parasites are an essential part of the aquatic ecosystem and represent a significant proportion of the aquatic biomass where most fishes bear a range of ecto- and endoparasites. The use of parasites in biomonitoring studies is based on the observations that healthy ecosystems are comprised of balanced populations of indigenous organisms with diverse structural and functional adaptations (Marcogliese, 2003).

The absence or presence of parasites depends on the availability of a suitable environment. There are certain factors that may determine the variety, composition and particularly the abundance of a parasite fauna. Factors of the external environment such as habitat, water temperature, flow rate and water quality might directly or indirectly influence both the prospective host and the parasite.

Fish parasites can be used as indicators of water quality, because of the variety of ways in which they respond to the pollution of the waters they inhabit. Pollution levels can decrease parasitism if the parasites are more susceptible to a particular pollutant than the host itself. Parasitism can also be decreased when the suitable intermediate host is affected or eliminated by a pollutant. Conversely, parasitism can be increased if the host defense mechanisms are negatively affected by the pollutant (Sures, 2006). The water quality may thus have a direct effect on the parasites itself or on the prevalence of their intermediate or final hosts, preventing the life cycle of the parasites to be completed. Rather than only monitoring physical and chemical parameters in water, the presence or absence of parasites can thus be used as a more sensitive monitoring method to reflect environmental conditions and possibly the health of the system. Hence in this survey the presence of endo and exto-parasites in and on fish caught were investigated.

Sampling of fish and parasites

As soon as the fish were removed from the gill nets/shocker nets, macroscopic examinations of the body surface, fins and mouth cavity was done for ectoparasites. Ectoparasites found, were removed by either using a fine brush or forceps and placed in glass containers filled with water from the site, for further processing in the field laboratory. Fish were transported to the field laboratory and kept alive in containers. Fish that could not be dissected were preserved in 70% ethanol for later examinations.

Skin and fin smears were made by scraping the skin and fins on both sides with a glass microscope slide. The slides were scrutinized for ectoparasites with the aid of a stereomicroscope. Each fish were weighed and measured and sex was determined. Fish were sacrificed by cutting through the spinal cord, and dissected to examine all internal organs and tissues.

The different organs, e.g. eyes, brain, heart, stomach**,** intestine, liver, spleen, swim bladder and urinary bladder were placed in separate petri-dishes containing saline solution. Organs were then examined for the presence of endoparasites with the aid of a stereomicroscope. The body cavity and body fat were inspected for parasites, and the muscles were thoroughly scrutinized for encysted parasites. All endoparasites recovered from each fish were counted, fixed using standard methods and preserved in 70% ethanol.

The gills were removed using dissection scissors and forceps, placed in petri-dishes containing water from the site, and examined for cysts, monogeneans and copepods. Gill arches were individually examined. The exact position of each parasite found was recorded according to a predetermined division of the gill arches and filaments. Monogeneans were removed and mounted on slides with glycerine jelly dissolved over a flame. Parasitic crustaceans were preserved in 70% ethanol.

The prevalence (percentage of hosts infected), mean abundance (mean number of parasites per examined host) and mean intensity (mean number of parasites per infected host) of each parasite were calculated according to Bush *et al*. (1997), as adapted from Margolis *et al*. (1982).

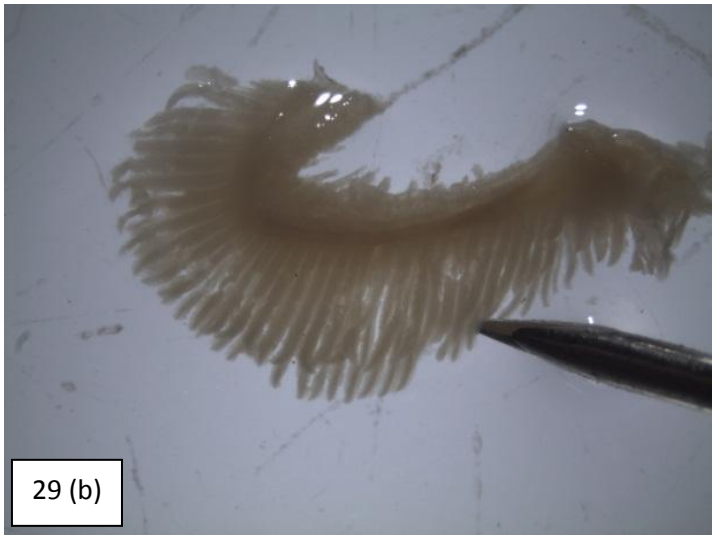


Figure 29 (a, b): Gills examined for the presence of parasites with the aid of a stereomicroscope.

Results

Five specimens of *Amphilius uranoscopus* collected from site 1 were investigated for metazoan parasites. The gills of four hosts (80%) were infected with an unidentified monogenean, ranging from 3 to 8 parasites per host (Table 5). Adult nematodes of the genus *Paracamallanus* York & Maplestone, 1926 was recorded from the intestines of 2 hosts (40%) and another unidentified adult nematode from the digestive tract of all hosts examined (Table 5).

Table 5. Prevalence, mean abundance, mean intensity and intensity range of parasites from *Amphilius uranoscopus*

Group	Parasite species	Site	P (%)	MA	MI	IR
Monogenea	Monogenean	Gills	80	4	5	3-8
Nematoda	*Paracamallanus* sp.	Intestine	40	0.8	2	1-3
Nematoda	Unidentified adult nematode	Digestive tract	100	2.6	2.6	1-4

P = Prevalence; MA = Mean abundance; MI = Mean intensity; IR = Intensity range

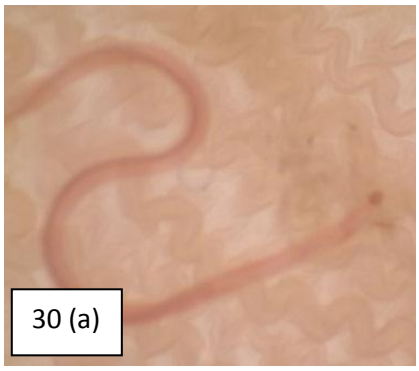


Figure 30 (a, b): a) The adult nematode *Paracamallanus* sp. (*in situ*) from the intestine of *Amphilius uranoscopus*. **b)** Anterior region of *Paracamallanus* sp. used for identification purposes.

Clarias gariepinus specimens collected from sites 11 - 13 were examined for metazoan parasites. Gills of 2 out of 5 host specimens (40%) were infected with the monogenean *Quadriacanthus* sp. Paperna, 1961, the intensity of infection ranging from 4 to 11 parasites per host (Table 6). A single unidentified adult nematode was recorded from the intestine of one of the host specimens (Prevalence 20%) (Table 6).

Table 6. Prevalence, mean abundance, mean intensity and intensity range of parasites from *Clarias gariepinus*.

Group	Parasite species	Site	P (%)	MA	MI	IR
Monogenea	*Quadriacanthus* sp.	Gills	40	3	7.5	4-11
Nematoda	Unidentified adult nematode	Intestine	20	0.5	1	1

P = Prevalence; MA = Mean abundance; MI = Mean intensity; IR = Intensity range

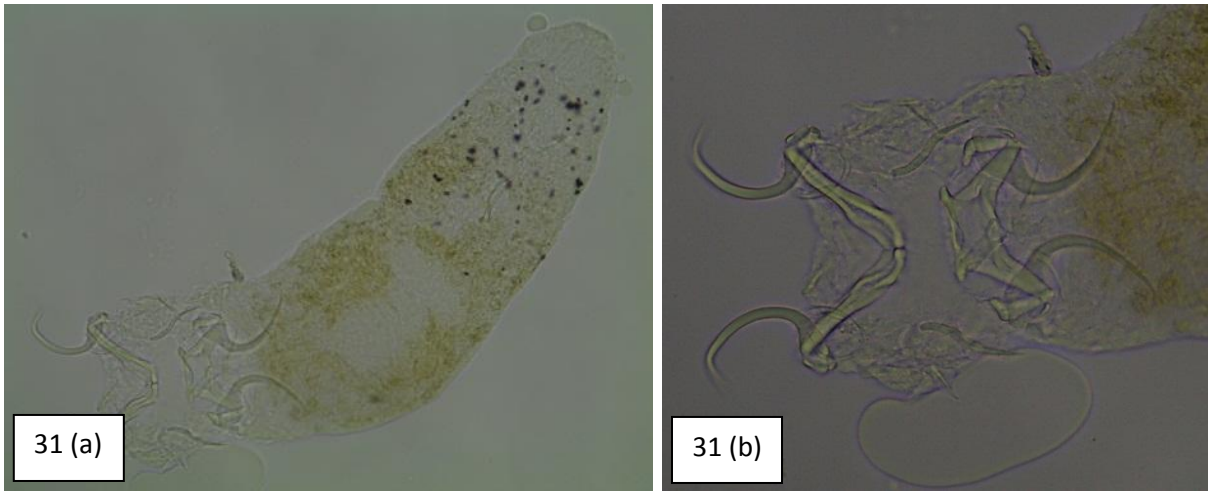


Figure 31 (a, b): a) A whole mount of the monogenean *Quadriacanthus* sp. from the gills of *Clarias gariepinus*. **b)** Opisthaptor (attachment organ) showing the haptoral sclerites of *Quadriacanthus* sp.

Figure 32 (a): The unidentified adult nematode from the intestine of *Clarias gariepinus*.

Labeo cylindricus specimens from sites 6, 10, 11 and 12 were investigated for metazoan parasites. From the 15 host specimens examined, the only parasites recorded were digenean cysts from the gills. These cysts were found on the gills of two (13.3%) hosts only, with the intensity of one and two respectively (Table 7).

Table 7: Prevalence, mean abundance, mean intensity and intensity range of parasites from *Labeo cylindricus*.

Group	Parasite species	Site	P (%)	MA	MI	IR
Trematoda	Diplostomum type larva	Gills	13.3	0.2	1.5	1-3

P = Prevalence; MA = Mean abundance; MI = Mean intensity; IR = Intensity range

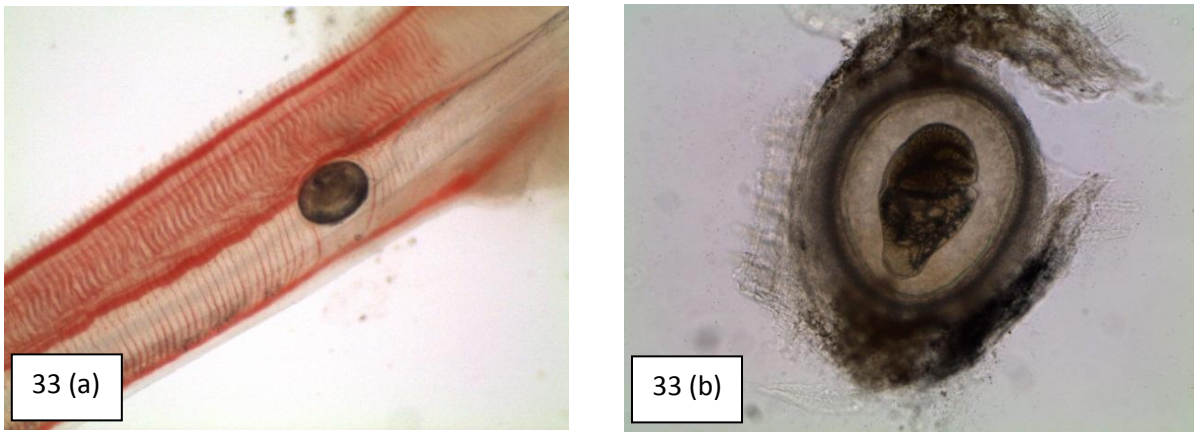


Figure 33 (a, b): a) Diplostomum type larva (Digenea) encysted on the gill filament of *Labeo cylindricus*. **b)** Diplostomum type larva visible inside the removed cyst.

A total of 15 specimens of *Oreochromis mossambicus* were collected from Lake Urema (Site 17) and investigated for metazoan parasites. A total number of 349 ectoparasites and 15 endoparasites consisting of five species were collected during this study. Two different groups of ectoparasites were recovered: Two species of copepods, *Ergasilus* sp. Stuhlmann, 1891 from the gills, and *Lernaea cyprinacea* Linnaeus, 1758 from the skin. The monogenean *Cichlidogyrus halli* (Price & Kirk, 1967) from the gills. Two goups of larval endoparasites were also recorded: The trematode *Euclinostomum* sp. Travassos, 1928 embedded in the muscle tissue and the nematode *Contracaecum* sp. from the body cavity. The parasite community was dominated by ectoparasites where all hosts were infected by *Ergasilus* sp. and *C. halli* and 13 (86.7%) hosts by *L. cyprinacea* (Table 4). *Contracaecum* sp. was recorded from 9 (60%) and *Euclinostomum* sp. from 2 (13.3%) of the hosts examined (Table 8). The mean abundance of ectoparsites was also notably higher than those of endoparasites (Table 8).

Lernaea cyprinacea exhibited an aggregated distribution and were attached mostly to the ventral and lateral regions of hosts, while the head was the least preferred attachment site. Although not all fish were infected by *L. cyprinacea*, it had the highest mean intensity of all parasites collected, ranging from 2-24 parasites per infected host (Table 8). The fish from which no *L. cyprinacea* were

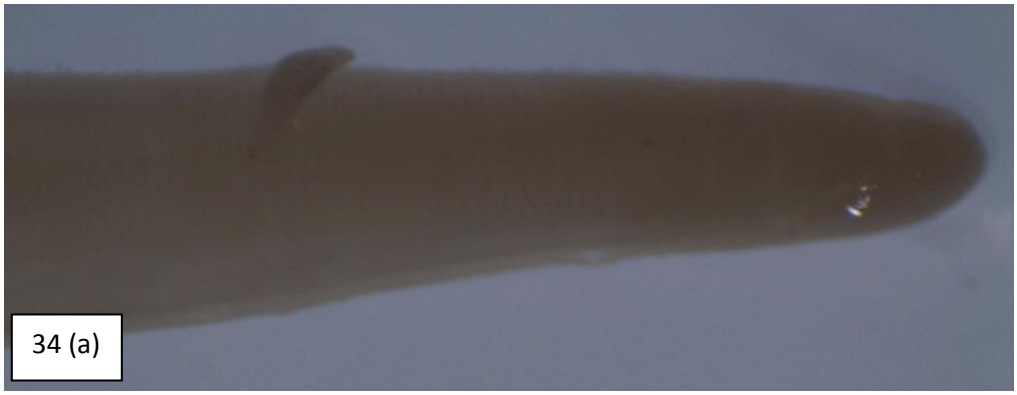
recorded still showed lesions of previous infections of this parasite. All fish from this survey thus showed lesions from current or previous damage caused by *L. cyprinacea* and in some cases signs of secondary infections at those areas (Figure 33 a).

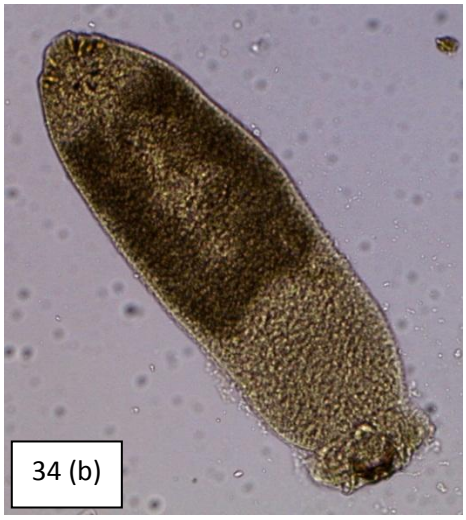
Females of the genus *Ergasilus* were attached to the gill filaments with their claw-like second antennae. The preferred attachment site was close to the gill arch near the base of filaments, but a small number of them were also attached nearer to the distal end of the filaments as shown in Figure 34. They were identified as adult females because of egg sacs present as well as the fact that *Ergasilus* spp. attach only after reaching sexual maturity (Smith 1949). The males of this parasite are free living, and thus not parasitic.

Table 8. Prevalence, mean abundance, mean intensity and intensity range of parasites from *Oreochromis mossambicus*

Group	Parasite species	Site	P (%)	MA	MI	IR
Monogenea	*Cichlidogyrus halli*	Gills	100	5.7	5.7	2-15
Trematoda	*Euclinostomum* sp. larva	Muscle	13	0.1	1	1
Nematoda	*Contracaecum* sp. larva	Body cavity	60	0.9	1.4	1-3
Copepoda	*Lernaea cyprinacea*	Skin	86.7	9.7	11.2	2-24
	Ergasilus sp.	Gills	100	7.8	7.8	2-28

P = Prevalence; MA = Mean abundance; MI = Mean intensity; IR = Intensity range





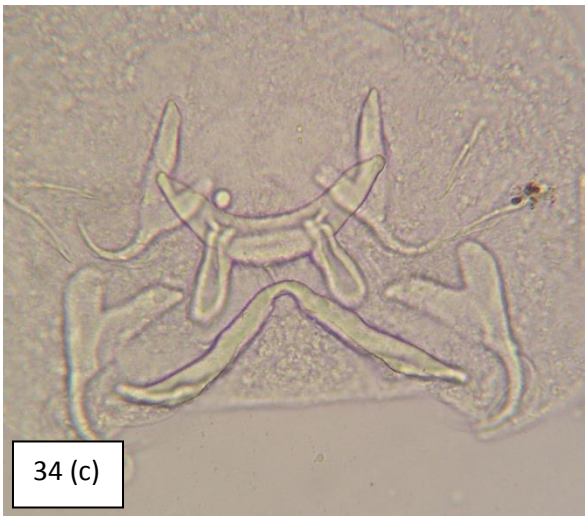


Figure 34 (a, b, c): a) The monogenean, *Cichlidogyrus halli* attached to the gill filament of *Oreochromis mossambicus*. **b)** Whole mount of *Cichlidogyrus* halli after removed from the gill. **c)** Opisthaptor (attachment organ) showing the haptoral sclerites of *Cichlidogyrus halli*.

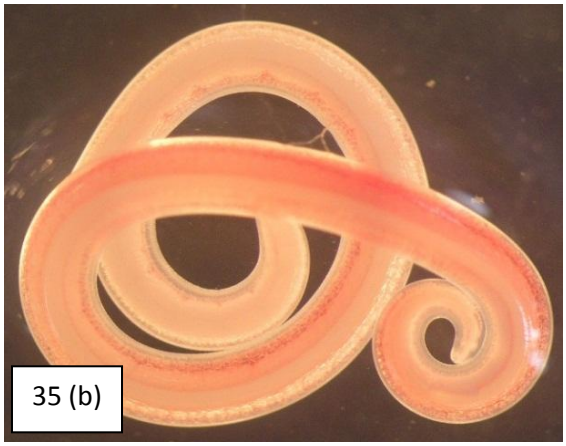


Figure 35 (a, b): a) *Eulinostomum* sp. larva (Digenea) from the muscle tissue of *Oreochromis mossambicus.* **b)** Contracaecum sp. larva (Nematoda) from the body cavity of *Oreochromis mossambicus*.

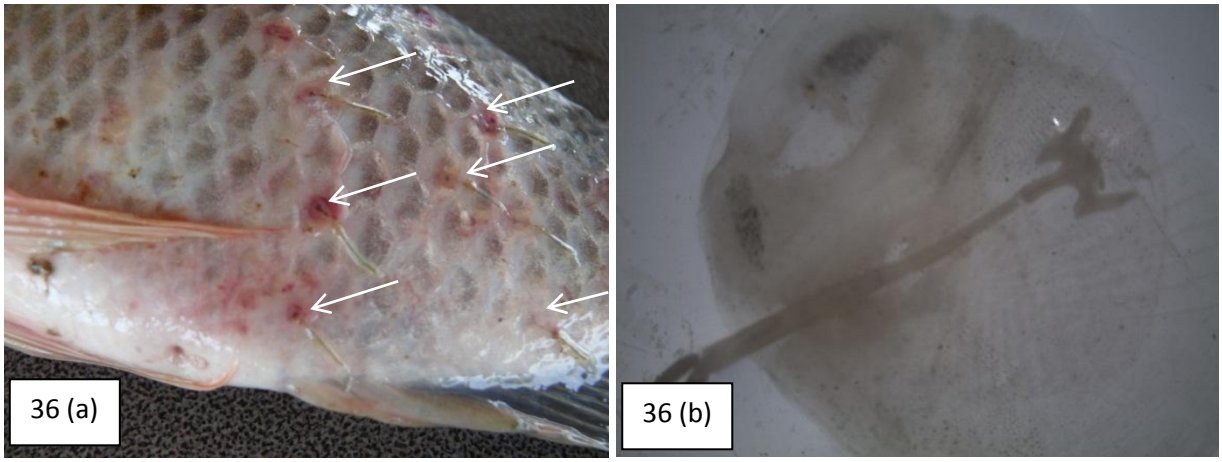


Figure 36 (a, b): a) The body of *Oreochromis mossambicus* with numerous individuals of *Lernaea cyprinacea* attached to it (indicated by arrows). Signs of inflammation are also visible on the fish. **b)** *Lernaea cyprinacea* removed from the skin and still attached to the ventral side of the scale. The attachment organ is visible on the anterior, and the egg sacs on the posterior end of the parasite.

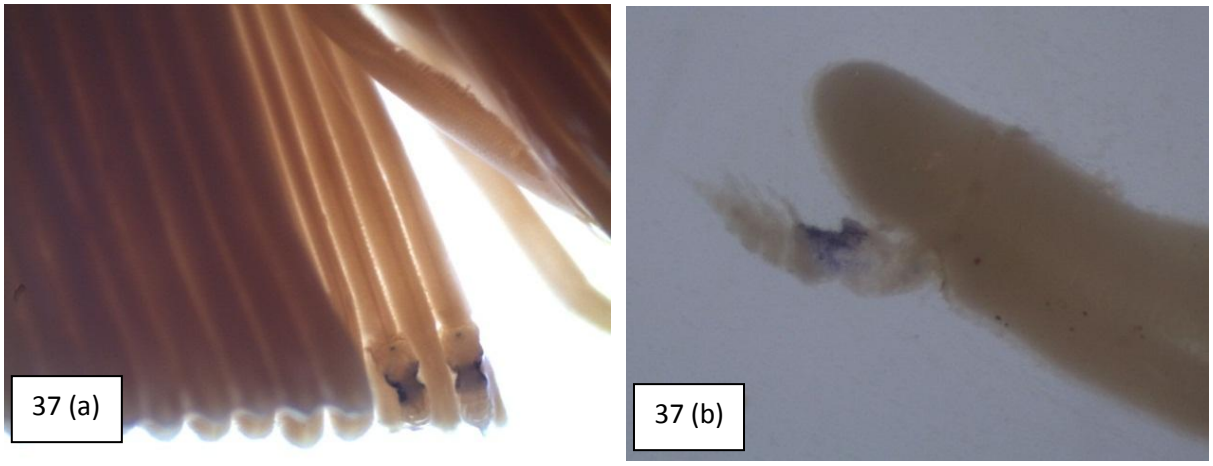


Figure 37 (a, b): a) *Ergasilus* sp. attached to the gill filaments of *Oreochromis mossambicus.* **b)** Note the damage to the epithelial layer of the gill filament at the site of attachment of this parasite.

Discussion

Endoparasites

The Diplostomum type larva, *Euclinostomum* sp. and *Contracaecum* sp. are all larval forms that use fish as an intermediate host. The adults normally occur in the gut of piscivorous birds such as pelicans, cormorants, herons and darters (Whitfield & Heeg 1977), but can also be found in mammals and crocodiles. The occurrence of these parasites has been widely reported in cichlids from Southern Africa. *Oreochromis mossambicus* is thus a potential intermediate host for at least

two, and *L. cylindricus* for at least one parasite species, whose life cycles are completed when these fishes are eaten by piscivorous animals.

Digenean trematodes such as Diplostomum type larva and *Euclinostomum* sp. have complex life cycles involving a series of hosts. Fish can be the primary or intermediate host depending on the digenean species. The life stage most commonly observed in fish is the metacercaria (larval stage), which encysts in fish tissues or externally on the gills or skin. The fish then functions as a transport host where the parasite sits and waits to be eaten by the appropriate vertebrate definitive host. It then becomes a reproductive adult, producing eggs which are excreted into the water with the faeces**.** Following this a miracidium hatches, which then go on to infect the first intermediate mollusc host. The miracidia go through several stages in the mollusc host, eventually emerging as motile cercaria larvae, to infect the second intermediate host (fish), where it is then known as metacercariae.

The life cycle of *Contracaecum* spp. is also complex. The eggs are released by gravid females into the intestinal tracts of their final hosts (a fish-eating bird or mammal), where they are excreted into the water with the faeces. The eggs hatch and the free-living larvae develop into the infective third-stage larvae (L3). These L3 larvae are then ingested by an invertebrate intermediate host, within which they develop even further. This invertebrate host is then ingested by the fish (intermediate host), where it remains until the intermediate fish host is eaten by the final host.

Adult nematodes such as *Paracamallanus* sp. and the other unidentified nematodes found in this survey use fish as their final host. In fish, adult nematodes are normally found in the digestive tracts. However, depending upon the species of nematode and the species of infected fish, adult and larval stages of nematodes can be found in almost any part of the fish. This includes the body cavity, internal organs (gut, swim bladder, bile ducts etc.), deeper layers of the skin or fins, and external muscle layers.

Paracamallanus spp. have indirect life cycles and are live-bearing nematodes. They are considered ovoviviparous, as females incubate the eggs which hatch into larvae within their bodies. These larvae are excreted into the water with the fish's faeces and are ingested by copepods or other crustaceans. Within the copepod, the larva develops further into a third-stage larva. After the copepod, containing the third-stage larva, is eaten by the appropriate fish host, the larvae migrate

out into the fish. The larva then develops into reproductive adults inside the intestinal tract of the fish, and the life cycle is complete.

Adult nematodes from the family Camallanidae is widely reported from a variety of fish species in African freshwaters. The *Paracamallanus* spp. recorded during this survey from *A. uranoscopus* is a new host record, as no parasites have been recorded for this fish species. The other unidentified adult nematodes recorded from this host will thus also be new records as soon as the worms are identified.

Ectoparasites

Monogeneans are the most common ectoparasites found on freshwater fish. They are found in all inland waters in Africa and many species and genera appear to be host specific. More than 28 ectoparasitic monogenean genera, including over 338 species have been recorded from African freshwater fishes.

Monogeneans are commonly found on the gills, skin or fins and are mostly browsers, moving about the body surface and feeding on mucus from the skin and gill debris. Monogeneans attach while feeding by using a series of hooks arranged in a special fashion (ophisthaptor). Most species are host- and site-specific, with direct life cycles, requiring only one host to reproduce. They reproduce by releasing eggs, or in some cases, live larvae into the water. The eggs hatch and mature prior to seeking a new host.

Quadriacanthus sp. and *C. halli* is frequently reported from *C. gariepinus* and *O. mossambicus* respectively in other African countries. No records on the monogeneans of *A. uranoscopus* could be traced in the literature. A gyrodactylid, *Gyrodactylus amphiliusi* is recorded from a fish in the same genus, *Amphilius atesuensis*, from Uganda. The monogenean specimens recorded from *A. uranoscopus* in the present study are recognised not to be from the genus *Gyrodactylus*, and further investigation is needed to identify this monogenean. Although there are previous records of two monogenean species from n *L. cylindricus* in Tanzania none could be recovered from the specimens dissected during this survey.

Parasitic Copepods are commonly found on freshwater fish, but may thrive under certain circumstances such as high water temperature and where fish becomes concentrated. Bulow *et al.*

(1979) emphasised that the intensity of infestation of *L. cyprinacea* is related to the water temperature, water velocity and stream order. As Dogiel (1962) stated, it is not only the host that provides the environment of parasites, but also the external environment. This is particularly obvious for the ectoparasites of aquatic animals, which depend directly both on the temperature and hydrochemistry of the external environment.

Telda & Fernando (1970) found that the intensity of infestation by *Ergasilus* sp. was higher in the winter than in the summer. One factor which may contribute to an increased infestation level during winter is the reduction in water volume due to shrinking of the water body. This may enhance the transmission of copepods between hosts as well as new infestations. The reduction in water volume can also have consequences on the community structure, such as increased competition and predation. Furthermore, the effort the fishes make to survive during the drying phase (e.g. competition for space and food, and predation avoidance) leads to an excessive energy waste, resulting in increased stress, which can intensify a vulnerability to parasitism.

More than 180 nominal species of *Ergasilus* have been described worldwide (El-Rashidy & Boxshall 2001; Montú & Boxshall 2002; Walter & Boxshall 2011). The overwhelming majority of species occurs in freshwater environments. Of those species 15 have been recorded throughout the African continent in all major river systems (Oldewage & Van As 1987; Oldewage & Avenant-Oldewage 1993; Abdel-Hady, et. al 2008). There are no published records of *Egasilus* spp. from *O. mossambicus* and it is thus a new host record for this parasite. The exact species of *Ergasilus* found, will be determined with further morphological investigation of this parasite.

The second antennae of this parasite are transformed into powerful hooks, holding the gill filaments tightly and can cause tissue damage and obstruct blood flow. Parasites feeding on epithelial cells stimulate hypertrophy and consequently a coalescence of secondary gill lamellae. This in turn drastically reduces the surface available for gas exchange. Lesions on gills are often attacked by secondary pathogens such as bacteria and fungi (Vinobaba, 2007).

Ergasilus has a direct life cycle that comprises six nauplius stages, five copepodid stages, and adults. *Ergasilus* can spend prolonged periods swimming free, and mating takes place while the male and female are swimming. Males die after copulation, while females remain attached to the fish host (Abdelhalim et al. 1991). The offspring hatch and are released into the water. They then undergo a series of moults before becoming adults.

Lernaea cyprinacea is an opportunistic species infecting various families of fish as well as larval amphibians (Yashuv, 1959). It is widely distributed in Eurasia, North America and southern Africa mainly via translocations of edible and ornamental cyprinids (Hoffman, 1970).

The female releases eggs into the water which hatch into free-swimming nauplii in 2-3 days. After a brief period of development, the first copepodid stage is reached and the parasite must find a fish host on which to live within a few days or it will die. The parasite continues to metamorphose, proceeding through a series of moults on the fish's skin. When the fifth copepodid stage is reached, males and females mate and the males die. The female then undergoes rapid elongation and metamorphosis of the cephalic region to produce the anchor process. While these morphological changes are in progress, the transforming female begins producing egg sacs (Shields & Goode, 1978). The anchor cause acute haemorrhage and ulcers at the area of penetration, and fatality may occur as a result of blood loss and secondary infections (Putz & Bowen, 1964).

Many factors may have an influence on the variety, composition and particularly the abundance of parasites. Ecological factors such as diet, gregarity, conspecific and total host density, habitat, body size, life span, vagility, and migration of the host may influence the number of parasites encountered and thus, parasite species richness (Morand *et al*. 2000). The composition and seasonal fluctuation of a parasite fauna are thus mainly due to the mode of life of the host. Factors from the external environment such as water temperature and water quality may affect the parasite itself or the intermediate hosts that is needed to complete the life cycle. The environmental conditions determine the general character of the parasite fauna as a whole and the absence or presence of parasites depends thus on the availability of a suitable environment for them.

It was expected to find high infestations of copepods in Lake Urema as it is known that this group of parasites thrive in shallow waters with high temperatures. The development of eggs, as well as the time from hatching to adult female stage increase at higher temperatures. This survey was conducted in the dry season when the volume of the lake was significantly reduced, and parasites could be transmitted more easily. It will thus be interesting to see how the infection statistics of this group of parasites change seasonally as temperature as well as water volume change.

The high flow rate of water in the river can be one of the reasons why copepods were absent from these sites. This fast moving water is unfavourable for the free living copepodid stages, as well as for

acquiring a host. Monogeneans on the other hand, do not have free-living stages and the next generation can develop on the same host. Monogeneans were recorded from the upper, mid, and lower regions of the river.

Fish-eating birds act as final hosts for numerous larval parasites found in fish, and is thus an essential part in the life cycle of these parasites. There were no fish-eating birds noticed around the upper reaches of the Vunduzi River. The first sign of fish-eating birds were in the region of site 10 and increased downstream to Lake Urema were they were abundant. This could be the reason why no larval parasites were recorded from the upper reaches of the river and only three larval specimens from the 15 *L. cylindricus* specimens examined in the mid region. Two species of larval parasites were recorded from Lake Urema, with *Contracaecum* sp. having a prevalence of 60%. Larval parasites were thus more prevalent where fish-eating birds were observed. Adult nematodes were recorded from the upper and middle regions of the river, which indicate the presence of their primary invertebrate hosts.

Parasitological surveys are very time consuming involving intense microscope work and specialized preservation techniques. For this reason all fish collected during this survey could not be processed in time for this report, but are preserved for later processing. There are no parasitological data available for fish parasites from Mozambique and these surveys will thus contribute to the global parasite database as well as knowledege of the Biodiversity of this country. New host records are already identified from the fish examined and the description of new parasite species can also follow.

Conclusion

The parasite survey identified different ectoparasites and endoparasites. The findings thus far have revealed that *Paracamallanus* spp. found *in Amphillius uranoscopus* and the *Egasilus* spp. from *Oreochromis mossambicus* are new host records for these parasites. Considerable work has yet to be done as some parasites have still to be identified. The use of fish parasites in the Vunduzi River needs to be investigated further.

Recommendations to management

Based on our findings, it is strongly recommended that the reforestation and protection of the Gorongosa Mountain 700 m contour be enforced. Moreover the riparian buffer zone criteria and no fishing policy should be extended to the 400 to 200 m contour in order to protect the rare and endangered *Parakneria mossambica*. The use of poisonous sap extracted from indigenous flora used by locals should be curtailed and prohibited as a means to catch fish. The element of seasonality, especially during the breeding and growth phase of this species in relation to the frequency of fishing in this area needs to be investigated.

That the conservation and importance of the Vunduzi River, including the riparian vegetation and species of fish therein should be taught in local village schools with particular emphasise placed on the importance of conservation.

That the reforestation of the mountain and subsequent protection should continue. This will help curtail deforestation and sediment build up caused by erosion. Sedimentation will have an influence on the river bed and will in turn alter existing habitats in the intermediate and upper reaches. Park management needs to enforce legal restrictions on land use affecting water sources, especially the 50 m riparian buffer zone under the Forest and Wildlife Act (10/1999) of Mozambique.

The effects of gold panning in the headwaters of some Pungwe tributaries remain a concern because of their impact on water quality due to the use of mercury by gold-panners to extract gold (Sweco and Associates, 2004). It has to be investigated whether gold mining activity is a relevant source of pollution in the catchment area of Lake Urema as a polluted Pungwe River will not facilitate the migration of andromous species from the ocean in the Vunduzi system.

Recommendation for future studies

The headwaters of the Vunduzi River should be investigated to establish if there are any species above the waterfall. If species are present then morphological aspects and genetic markers should be used to compare if they form distinct populations. Future studies that are descriptive of the various habitats, should establish the nutrient load by measuring various chemical parameters.

The number of people engaged and the type of fishing techniques used should also be investigated whereby the following can be addressed;

The means by which fish are utilisation *i.e.* consumed, traded locally or exported;

The income generated from fishing, fish processing and trading;

Which groups of the local population are direct beneficiaries?

More importantly to what effect the use of poison may have on the local population of fish killed especially a vulnerable species such as *Parakneria mossambica*.

The fishery potential on Lake Urema should also be investigated. Depending on the outcome subsistence fishing could give way to artisanal fishing whereby fish can either be sold or supplied to nearby villages and possibly to those people in the buffer zone where fishing is to be prohibited.

The parasite fauna found in the Vunduzi should be investigated further and compared to provide a better understanding of the life cycles, ecology and distribution of fish parasites. New parasite species identified and described can contribute to the global parasite database.

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APPENDIX A

All drawings herein are derived from Skelton (2001)

FISH CAUGHT AT THE VARIOUS SITES

Malapteruridae

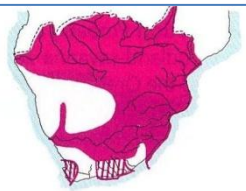
ZAMBEZI ELECTRIC CATFISH

Malapterurus shirensis Roberts (2000)

Clariidae

SHARPTOOTH CATFISH

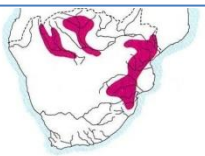
Clarias gariepinus Burchell (1822)

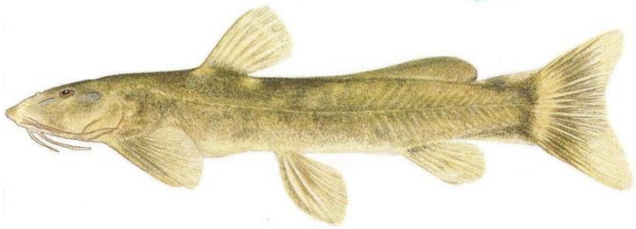


Amphiliidae

Mountain Catfish

Amphilius uranoscopus Pfeffer (1822)



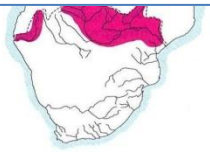


Broadtail Mountain Catfish

Amphilius laticaudatus Skelton (1984)

Mochokidae

Neumann's Suckermouth



Chiloglanis neumanni Boulenger (1911)

Shortspine Suckermouth

Chiloglanis pretoriae Van der Horst (1931)

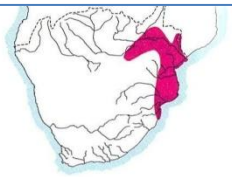
Kneriidae

Gorongoza Kneria

Parakneria mossambica Jubb & Bell-Cross (1974)

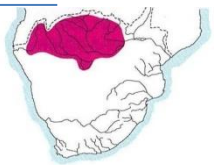
Cyprinidae

Broadstriped Barb



Barbus annectens
Gilchrist & Thompson (1917)

Barotse Barb



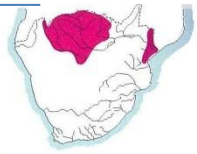
Barbus barotseensis Pellegrin (1920)

Cyprinidae (*cont*)

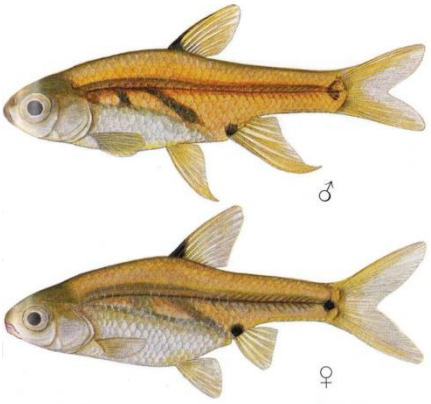
Hyphen Barb

Barbus bifrenatus Folwer (1935)

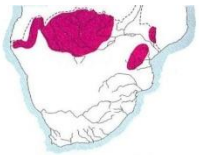
Sickle-Fin Barb



Barbus haasianus David (1936)



Redspot Barb



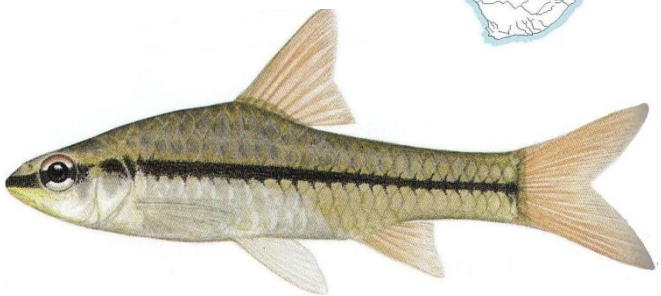
Barbus kerstenii Peters (1868)

Line-spotted Barb

Barbus lineomaculatus Boulenger (1903)

Beira Barb

Barbus radiatus Peters (1853)



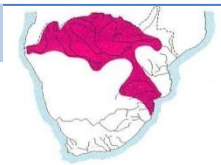
Threespot Barb

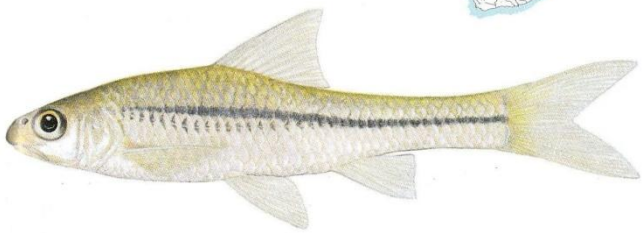
Burbus trimaculatus Peters (1852)

Cyprinidae (*cont*)

Longbeard Barb

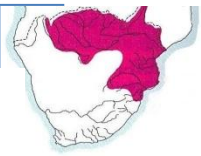
Barbus unitaeniates Günther (1866)





Redeye Labeo

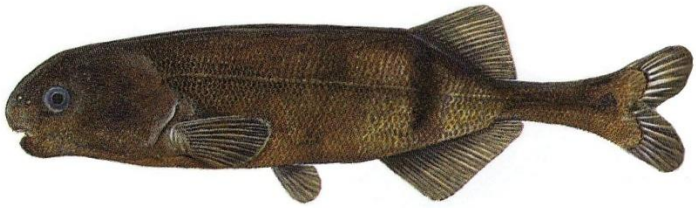
Labeo Cylindricus Peters (1852)



Mormyridae

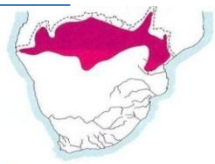
Slender Stonebasher

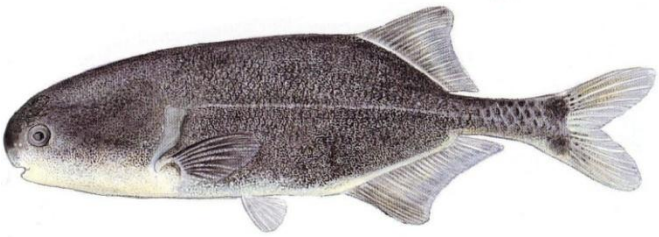
Hippopotamyrus ansorgii
Boulenger (1905)



Northern Churchill

Petrocephalus catostoma
Günther (1866)





Characidae

Imberi

Brycinus imberi Peters (1852)

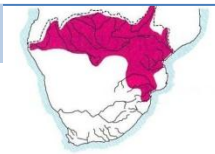
Striped Robber

Brucinus lateralis Boulenger (1900)

Characidae (*cont*)

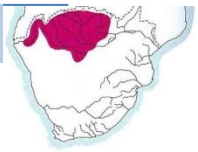
Silver robber

Micralestes acutidens Peters (1852)



Slender Robber

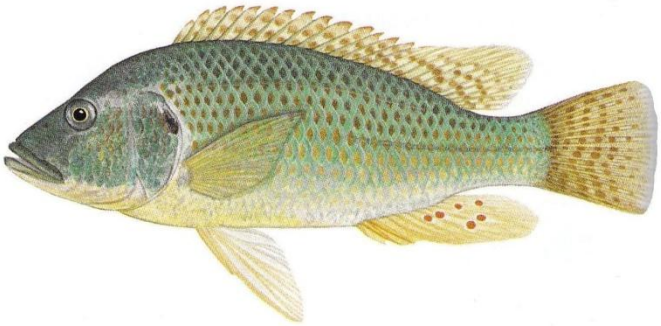
Rhabdalestes maunensis
Fowler (1935)



Chichlidae

Canary Kurper

Chetia flaviventris Trewavas (1961)

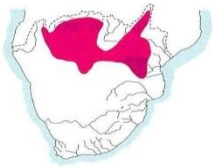


Mozambique Tilapia

Oreochromis mossambicus Peters (1852)

Zambezi River Bream

Pharyngochromis acuticeps
Steindachner (1866)



Redbreast Tilapia

Tilapia rendalli Boulenger (1896)

Chichlidae (*cont.*)

Orange-Fringed River Bream

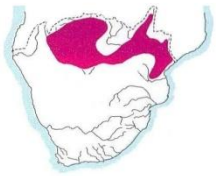
Chetia brevis Jubb (1968)

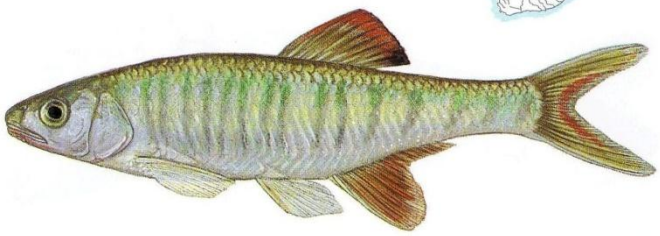
Additional species caught during the preliminary sampling trip

Cyprinidae (*cont.*)

Northern Barred Minnow

Opsaridium zambezense Peters (1852)





Characidae

Tigerfish

Hydrocynos vittatus Castelnau (1861)