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Impact of *Lernaea cyprinacea* Linnaeus 1758 (Crustacea: Copepoda) almost a decade after an initial parasitic outbreak in fish of Malilangwe Reservoir, Zimbabwe

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ABSTRACT

Key-words: Lernaea cyprinacea, Clinostomoides brieni, *parasite, cichlids, intensity, Malilangwe*

An assessment was carried out on the impact of *Lernaea cyprinacea* on fish populations ten years after its first outbreak in the Malilangwe reservoir, and *Lernaea cyprinacea* is currently showing no sign of declining in the reservoir. Eight fish species were examined for ectoparasite prevalence and intensity. The possible relationship between *L. cyprinacea* infestation and environmental factors were investigated. Two parasite species, *L. cyprinacea* in *Oreochromis mossambiccus, Oreochromis placidus*, *Oreochromis macrochir, Labeo altivelis* and *Tilapia rendalli* and trematode cysts *(Clinostomoides brieni)* in *Clarias gariepinus* were found. *Lernaea cyprinacea* prevalence was 100% amongst all cichlids but varied for *L. altivelis*. Parasite intensity increased during the cool, dry season (May to July), with the greatest mean intensity being observed amongst the cichlids. There was a significant relationship between parasite intensity and environmental factors; dissolved oxygen ($p < 0.05$), temperature ($p < 0.001$) and pH ($p < 0.001$).

RÉSUMÉ

Impact de la *Lernaea cyprinacea* (Crustacea : Copepoda) près d'une décennie après une première épidémie parasitaire chez les poissons du réservoir Malilangwe, Zimbabwe

Mots-clés : Lernaea cyprinacea, Clinostomoides brieni, *parasite, cichlidés, prévalence*

Une évaluation a été réalisée sur l'impact de *Lernaea cyprinacea* sur les populations de poissons dix ans après sa première apparition dans le réservoir Malilangwe. *Lernaea cyprinacea* ne montre actuellement aucun signe de déclin dans le réservoir. Huit espèces de poissons ont été examinées pour la prévalence et l'intensité des ectoparasites. La relation possible entre l'infestation de *L. cyprinacea* et les facteurs environnementaux a été étudiée. Deux espèces de parasites, *L. cyprinacea* dans *Oreochromis mossambiccus*, *Oreochromis placidus*, *Oreochromis macrochir*, *Labeo altivelis* et *Tilapia rendalli* et les kystes de trématode (*Clinostomoides brieni*) dans *Clarias gariepinus* ont été trouvés. La prévalence de *Lernaea cyprinacea* était de 100 % chez tous les cichlidés, mais variable pour *L. altivelis*. L'intensité parasitaire a augmenté au cours de la saison fraîche et sèche (de mai à juillet) avec une intensité moyenne plus grande observée parmi les cichlidés. Il y avait une relation significative entre l'intensité du parasite et des facteurs environnementaux ; oxygène dissous ($p < 0,05$), la température ($p < 0,001$) et le pH ($p < 0,001$).

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INTRODUCTION

Fish parasites are very common throughout the world and are of particular importance in the tropics (Moyo *et al*., 2009). Parasites affect fish health, growth and survival (Barson and Marshall, 2003). *Lernaea cyprinacea* Linnaeus, 1758 (Crustacea: Copepoda), commonly known as “anchor worm”, is an important crustacean parasite of freshwater fish that has a wide geographic range (Silva-Souza *et al*., 2000; Nagasawa *et al*., 2007; Hoffman, 1999).

Lernaea species have nine stages in the life cycle, including three free-living naupliar stages, five copepodid stages and one adult stage. After mating on the fish host, the males die and females metamorphose and insert their anterior body into the host tissue and then produce eggs (Nagasawa *et al*., 2007; Barson *et al.*, 2008b). Anchor worm infections usually result in a single parasite per host fish in flowing rivers and streams, causing a little damage, but in closed environments severe infestations often result (Demaree, 1967).

The complex life cycles that parasites possess make them extremely valuable information units on aquatic environmental conditions since their presence or absence tells us a great deal about not only their host ecology but also food web interactions, biodiversity and environmental stress (Madanire-Moyo and Barson, 2010). Combining different species based on shared patterns of transmission provides a potentially more powerful indicator of prevailing environmental conditions (Moyo *et al*., 2009; Madanire-Moyo and Barson, 2010).

Knowledge on the fish parasites in Zimbabwe is limited to studies that were done in Lake Kariba (Chishawa, 1991; Douellou, 1992), in the upper Manyame catchment including Lake Chivero (Barson and Marshall, 2003; Barson, 2004; Madanire-Moyo and Barson, 2010; Taruvinga, 2011) and the south-eastern lowveld rivers (Barson *et al*., 2008a). No meaningful work has been done on fish parasites in small dams except work carried out by Barson *et al.* (2008b) in Malilangwe Reservoir, Moyo *et al*. (2009) in Insukamini Dam and Taruvinga (2011) in Harava and Seke Dams.

In 2002, a parasitic infestation of *L. cyprinacea* was observed on several *Oreochromis* species in Malilangwe Dam (Bruce Clegg, personal observation). This parasite being a one-host parasite, it probably arrived either *via* infected fish from the surrounding Runde catchment or from human introductions of infested fish. At the time water levels in the dam were very high following the tropical cyclone Eline in 2000, and it is possible that the prevailing flood conditions could have brought the infested individuals into the otherwise isolated Malilangwe Dam. Subsequent investigation by Barson *et al.* (2008b) revealed that the parasite had affected almost 100% of the population of the species involved, with little or no apparent seasonal variation, somehow suggesting that the parasite was trapped in a more or less isolated system.

The purpose of this study was to assess the current status of *L. cyprinacea* infestation, about nine years following its initial appearance on fish of the Malilangwe reservoir. We also aimed to investigate its distribution within the different seasons and assess the general prevalence and intensity of fish parasitism within the reservoir.

> *STUDY AREA*

Malilangwe Wildlife Reserve is located in the Chiredzi District of the south-eastern lowveld of Zimbabwe (20° 58′ 21° 02′ S, 31° 47′ 32° 01′ E) (Figure 1). It arises from an impounded river formed in 1964 and is used for water supply in the reserve. Itis situated on the Nyamasikana River, a tributary of the Chiredzi River which in turn flows into the Runde River. It is a gravity section masonry dam with a surface area of 211 hectares with maximum volume of 1.2×10^7 m^3 at full capacity. Flanked by rocky hills on most of its sides, the impoundment has a rocky substrate with few sandy bays. It is poorly vegetated with a few marginal plants including *Azolla filiculoides* (Lam), *Ludwigia stolonifera* (Guill and Perr) Raven, *Panicum repens* (Lam), *Schoenoplectus corymbosus* (Roth ex Roem and Schult) Raynal *Potamogeton pusillus* Linnaeus, *P. crispus* Linnaeus, *P. tricarinatus* Benn *Phragmites mauritianus* (Kunth) and

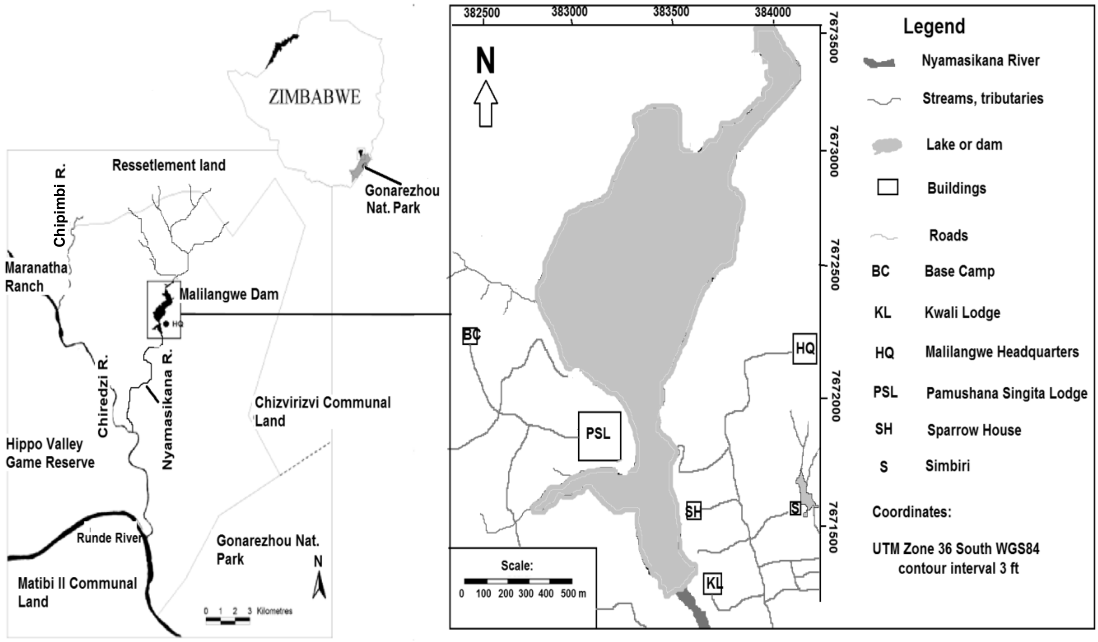

Figure 1
Location of littoral zone sampling sites around Malilangwe Reservoir (shaded area).

Cyperus sp The fish communities include predators, omnivores, detritivores, and micro- and macrophages (Dalu *et al*., unpubl. data; Barson *et al.*, 2008b).

METHODS

> *FISH SURVEYS*

Sampling was carried out monthly for 9 months (February to October 2011). The sampling program was done using three types of fishing gear: fyke nets, a seine net and gill nets. Fyke nets were used in the shallow parts (<1 m) while gill nets were set in the deeper sections (>1.5 m) of the dam. Three double fyke nets with a stretched mesh size of 24 mm connected by a 12.5-m-long net giving a total length of 18 m were set overnight at randomly selected sites. A fleet of nylon multifilament gill nets with stretched meshes of 12, 20, 30, 40, 50, 72, 100, 128 and 140 mm were used in February and March 2011 and cotton multifilament nets with stretched meshes of 7, 12, 20, 30, 40, 50, 60 and 72 mm were used throughout the sampling period, and both nets were set overnight for 12–14 h. A Seine net with mesh size of 18 mm was also used only in June 2011. Gill nets were used more extensively compared with the other fishing gears. Fish were identified by different freshwater fish guides of Southern Africa (Skelton, 2001; Marshall, 2010). Fish standard length was measured to the nearest cm and they were weighed in kgs.

A method used by Barson *et al.* (2008b) was used for *L. cyprinacea* parasite identification with all live and healthy fish being returned to the reservoir. The external body surfaces as well as the gill chamber and mouth cavities of each fish were examined for the presence of adult female *L. cyprinacea*. Fish parasite intensity was determined by counting the number of adult *L. cyprinacea* and cutaneous lesions about 4 mm in diameter were included according to Grabda (1963). The lesions were assumed to be sites of *L. cyprinacea* attachment as parasites are sometimes dislodged during fish handling. Parasite prevalence per fish species was determined by calculating the number of fish infested with adult female *L. cyprinacea* as a percentage of the total number of fish examined (Barson *et al.*, 2008b). Mean parasite intensity for each host species was obtained by dividing the total number of *L. cyprinacea* in a sample of a host species by the number of infested individuals of the host species in the sample (Barson *et al.*, 2008b).

A Pearson correlation between parasite intensity and physicochemical variables was carried out using SysStat ver. 12 to test if environmental variables have an influence on parasite intensity. Analysis of parasite intensity and study months was carried out using SysStat ver. 12 and the data followed an ordinal rating, which violates various ANOVA assumptions. Hence, the data was not normal as confirmed by the Shapiro-Wilk normality test. Therefore, the non-parametric equivalent of a two-way ANOVA, the Kruskal–Wallis ANOVA test ($p < 0.05$), was used to test for the significant effect of parasite intensity and different study months.

> *BASIC WATER QUALITY MEASUREMENTS*

Water was collected at each site (five sampling points) and measurements of pH, conductivity, total dissolved solutes, temperature and dissolved oxygen (*DO*) were made using water quality sensors (Hach LDO®, Germany). Water transparency was measured using a Secchi disk. Chemical oxygen demand (COD), nitrogen, nitrates, and total and reactive phosphorus were determined using methods from the EPA (Environmental Protection Agency), Hach and Standard Methods.

RESULTS

> *ENVIRONMENTAL VARIABLES*

Table I summarizes the mean values of environmental variables in the Malilangwe reservoir for the study period. Dissolved oxygen (*DO*) values were low during February to March, and increased between May and August before dropping in September to October. Well-oxygenated water was found throughout the cool, dry season (7–9 $\text{mg}\cdot\text{L}^{-1}$) as a result of reservoir turnover (complete mixing of the water body). The lowest *DO* levels of up to 5–5.6 $\text{mg}\cdot\text{L}^{-1}$ were in March, August, September and October. The lowest water temperature occurred from May to September after which there was a rapid increase. Temperature decreased through the two seasons (hot, wet – cool, dry). The temperature was 29.7 °C in February before decreasing to a low of 19.3 °C in July. Temperatures then increased from July (19.3 °C) to October (27.6 °C). The highest temperatures were recorded in February (29.7 °C) and the lowest in July (19.3 °C). Secchi disk readings ranged between 0.2–1.6 m (Table I).

Ammonia and nitrogen were shown to decrease during the cool, dry season, especially during May to July. Low levels of nitrogen ($N = 0.4$ $\text{mg}\cdot\text{L}^{-1}$) were recorded in August. Ammonia values were high in March (0.4 $\text{mg}\cdot\text{L}^{-1}$) and below the detection limit in February. Low values of ammonia were observed during the hot, dry season. Nitrate values were below the detection limit (LOD) in July, March and September but increased in August (0.01 $\text{mg}\cdot\text{L}^{-1}$) and October (0.02 $\text{mg}\cdot\text{L}^{-1}$). Nitrate was high in June (0.03 $\text{mg}\cdot\text{L}^{-1}$) and May (0.03 $\text{mg}\cdot\text{L}^{-1}$). Alkalinity showed slight seasonal changes and it fluctuated between 17 and 19.4 $\text{mg}\cdot\text{L}^{-1}$ for the study months. Total dissolved solutes (TDS) were high during April to July (278.4–344.9 $\text{mg}\cdot\text{L}^{-1}$). There was an increase in conductivity from March (191.6 $\mu\text{S}\cdot\text{cm}^{-1}$) to September (228.1 $\mu\text{S}\cdot\text{cm}^{-1}$) (Table I).

> *PARASITE PREVALENCE AND INTENSITY*

Eight fish species; *Oreochromis macrochir*, *Oreochromis mossambicus*, *Oreochromis placidus*, *Tilapia rendalli*, *Glossogobius giuri*, *Labeo altivelis*, *Hydrocynus vittatus* and *Clarias gariepinus* caught in the Malilangwe reservoir were examined for parasites (Table II). Only

Table I
Descriptive statistics of the measured environmental variables in Malilangwe reservoir (February to October 2011), SD = standard deviation and LOD = below the detection limit.

Parameter	Unit	Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Dissolved oxygen	mg·L^{-1}	6.6	1.2	5.0	0.8	7.8	0.3	7.0	0.3	7.9	0.3	8.5	0.5	5.6	0.4	5.6	1.0	5.3	1.1
Temperature	°C	29.7	0.9	30.1	0.8	26.9	0.7	24.4	0.1	21.6	0.3	19.3	0.5	20.9	2.1	22.5	2.1	27.6	0.8
Conductivity	μS·cm^{-1}	333.0	14.1	191.6	11.2	358	6.2	358.3	3.4	367	1.3	376	2.2	338.4	22.5	360.3	34.1	433.3	5.9
pH		7.8	0.3	7.9	0.2	7.9	0.3	7.9	0.1	8.6	0.2	8.9	0.1	7.5	0.4	7.8	0.7	7.5	0.3
Total dissolved solutes	mg·L^{-1}	300.6	12.1	235	3.7	344.9	1.8	278.4	1.9	284.7	0.8	292.2	1.6	226.7	8.0	228.1	19.8	252.6	1.0
Reactive phosphorus	mg·L^{-1}	0.3	0.1	0.3	0.2	0.1	0.1	0.2	0.1	0.6	0.1	0.1	0.02	0.1	0.03	0.7	0.3	0.8	0.1
Nitrogen	mg·L^{-1}	0.7	0.8	1.7	1.0	0.8	0.6	1.1	1.0	0.7	0.5	1.0	0.9	0.4	0.1	0.9	1.2	1.2	1.1
Ammonia	mg·L^{-1}	LOD	0.0	0.4	0.2	0.1	0.05	0.2	0.2	0.03	0.02	0.1	0.1	0.1	0.03	0.002	0.04	0.1	0.1
Nitrate	mg·L^{-1}	0.1	0.2	LOD	0.0	0.1	0.01	0.03	0.02	0.03	0.01	LOD	0.0	0.01	0.01	LOD	0.0	0.02	0.01
Chemical oxygen demand	mg·L^{-1}	30.1	8.9	27.6	12.4	56.8	15.3	26.1	4.0	19.5	1.2	27	21.4	86.6	20.8	35.1	14.8	25.2	23.9
Total phosphorus	mg·L^{-1}	0.6	0.2	0.8	0.4	0.01	0.1	0.2	0.05	1.4	0.3	0.1	LOD	0.0	0.1	2.5	1.5	1.9	0.2
Secchi depth	m	1.1	0.1	1.0	0.3	1.1	0.5	1.6	0.4	1.0	0.3	1.2	0.5	1.3	0.2	1.1	0.1	0.7	0.3
Alkalinity	mg·L^{-1}	–	–	17.0	1.2	18.7	0.8	18.6	1.5	18.6	1.4	18.1	1.3	17.8	2.0	19.1	1.5	19.4	1.6

Table II
Prevalence and intensity of Lernaea cyprinacea in susceptible fish species present in Malilangwe reservoir. N = number of studied fish.

Species present	*N*	Prevalence (%)	Intensity		Month
			Mean	Range	
Labeo altivelis	15	26.67	3	1–5	February
Oreochromis macrochir	4	100.00	21	12–31	
Oreochromis mossambicus	13	100.00	20	2–41	
Oreochromis placidus	32	100.00	16	3–40	
Labeo altivelis	98	17.35	7	1–16	March
Oreochromis macrochir	16	100.00	26	5–44	
Oreochromis placidus	27	100.00	25	9–62	
Tilapia rendalli	1	100.00	8	8	
Labeo altivelis	95	32.63	12	2–31	April
Oreochromis macrochir	22	100.00	33	18–64	
Oreochromis mossambicus	28	100.00	32	9–59	
Oreochromis placidus	35	100.00	28	5–61	
Labeo altivelis	116	38.79	34	7–89	May
Oreochromis macrochir	30	100.00	42	2–88	
Oreochromis mossambicus	55	100.00	42	5–91	
Oreochromis placidus	37	100.00	40	8–90	
Labeo altivelis	112	45.54	37	3–89	June
Oreochromis macrochir	50	100.00	78	4–153	
Oreochromis mossambicus	27	100.00	71	10–152	
Oreochromis placidus	47	100.00	74	9–158	
Labeo altivelis	91	34.07	30	12–71	July
Oreochromis macrochir	49	100.00	75	19–175	
Oreochromis mossambicus	27	100.00	69	10–153	
Oreochromis placidus	50	100.00	78	18–192	
Labeo altivelis	82	24.39	16	3–21	August
Oreochromis macrochir	25	100.00	31	5–82	
Oreochromis mossambicus	24	100.00	29	9–78	
Oreochromis placidus	34	100.00	40	8–101	
Labeo altivelis	93	17.02	16	3–21	September
Oreochromis macrochir	29	100.00	22	2–56	
Oreochromis mossambicus	37	100.00	27	8–78	
Oreochromis placidus	37	100.00	26	8–67	
Tilapia rendalli	2	100.00	5	2–8	
Labeo altivelis	127	20.31	12	3–31	October
Oreochromis macrochir	26	100.00	29	9–67	
Oreochromis mossambicus	41	100.00	30	9–56	
Oreochromis placidus	30	100.00	20	5–36	
Tilapia rendalli	1	100.00	13	13	

cichlids and one cyprinid (*L. altivelis*) were infected with *Lernaea cyprinacea* and had different parasite intensities across the months with $p = 0.0$ (Kruskal-Wallis ANOVA) (Table II). The parasite prevalence was low in *Tilapia rendalli* (small sample size, $n = 4$) and *Labeo altivelis* but much higher in the other three cichlids (*O. macrochir, O. mossambicus* and *O. placidus*). Parasite prevalence was 100% throughout the nine study months amongst the cichlids whilst it varied across the study months for cyprinidae (Table II). Parasite intensity differed greatly amongst host species with the *Oreochromis* sp. being the most infected ($p = 0.0$). Parasite intensity increased during the winter period (May to July) as algal blooms formed in the reservoir with $p = 0.0$ (Kruskal-Wallis ANOVA) (Table II). Eight individuals of catfish, *C. gariepinus*, were found to be heavily infected with trematode cysts (*Clinostomoides brieni*) in the skin during the hot, wet ($n = 7$) and early months of the cool, dry season ($n = 2$). No further catfish species were observed that were infected by the cysts. No infections were found in the tigerfish (*H. vittatus*), catfish (*C. gariepinus*) or the goby (*G. giuris*).

Table III
Pearson correlation coefficients and significance levels between the physicochemical variables and parasite intensity ($p < 0.05$, ** $p < 0.001$).*

Parameter	Correlation coefficient (r)
Dissolved oxygen	0.727*
Temperature	–0.801**
Conductivity	0.26
pH	0.683*
Total dissolved solute	0.19
Nitrogen	–0.237
Ammonia	–0.144
Nitrate	–0.378
Chemical oxygen demand	–0.307
Total phosphorus	0.01
Secchi depth transparency	0.18

A Pearson correlation of physicochemical variables with parasite intensity showed that parasite intensity was significantly correlated with dissolved oxygen, temperature and pH. Thus, parasite intensity was negatively correlated with temperature and positively correlated with dissolved oxygen and pH (Table III).

DISCUSSION

The presence of *L. cyprinacea* on some fish species (*O. placidus, O. mossambiccus*, *O. macrochir*, *L. altivelis* and *T. rendalli*) and not others (*C. gariepinus, G. giuris* and *H. vittatus*) in Malilangwe reservoir suggests that *L. cyprinacea* is host-specific. Whitaker and Schlueter (1975) and Barson *et al.* (2008b) suggested that the differences in susceptibility of fish species to the parasite could be due to differences in ecological, behavioural and physiological mechanisms, and morphological variations. Some fish species such as the scale-less *C. gariepinus* might produce hormones or secrete mucous which might make them unacceptable to the copepod or make them immune. The structure and arrangement of scales in some fish species such as *H. vittatus* might not allow for easy implantation of the parasite's anchor as they are tightly packed.

The most abundant fish species *Labeo altivelis* was found to have the lowest rates of *Lernaea* infestation. Whitaker and Schlueter (1975) suggested that abundant species seem to have had more opportunity to evolve such defence mechanism devices, particularly if they had been abundant over rather long periods of time. Such mechanisms would seem more likely to have evolved if the parasite tended to cause severe harm to the host. *Clarias gariepinus* and *Labeo altivelis*, which are associated with muddy habitats, were found to be the least infected species, with no parasites being observed in *C. gariepinus*. These findings are in contradiction with Demaree (1967), who reported that fish collected from muddy water and the muddy bottom were most frequently infected with *L. cyprinacea*.

In our study, the copepod parasite infection in *O. placidus* was very high during the cool, dry season and when most of the reservoir was covered in algal blooms. The high parasite infection in the smaller cichlid of the four species found in Malilangwe is supported by Amin *et al*. (1973), who found smaller host fish to be more heavily infested, but Sanchez-Hernandez (2011) showed that in brown trout, the prevalence was higher (3+) but the number of *L. cyprinacea* was not related to age Whitaker and Schlueter (1975) and Barson *et al.* (2008b) found that higher parasite intensity in smaller and younger fish could be because these fish are easily accessible to the parasite or their defence mechanisms are less well developed compared with larger or older fish. In the present study small fish were caught in the littoral zones of the reservoir as they seek refuge from predators in the macrophytes and substrates, but these warm littoral zone areas are also the preferred habitats of *L. cyprinacea*, as noted by Paperna (1996). Therefore, chances of juvenile fish infection are very high. *Clarias gariepinus* was found to be affected by trematode cysts (*Clinostomoides brieni*) during the hot, wet and cool, dry seasons. The cysts covered the whole fish body and also changed the skin colour of fish to a light grey. The number of cysts per host were higher during the rainy season, which may suggest a link with climatic and environmental factors.

Water quality in the Malilangwe reservoir could be contributing to the high parasite prevalence observed in the fish. Malilangwe reservoir has not overflowed in the last 12 years since Cyclone Eline of 2000 and the reservoir only outflows when it is at full capacity; thus, the biota is essentially isolated. The pH was very highly positively correlated with parasite intensity ($r = 0.727$, $p < 0.001$) while temperature was very highly negatively correlated with parasite intensity ($r = -0.801$, $p < 0.001$). Barson *et al.* (2008b) showed that high water temperatures contributed to fast development of the copepod parasite but our study seem to suggest otherwise; during the cool, dry season, parasite intensity increased with mean temperatures of 19 °C, suggesting that temperature only is not a major factor in the increase in parasite intensity. The temperature and water level fluctuations observed in Malilangwe reservoir during the cool, dry season could have contributed to the increased infestation by *L. cyprinacea* in the reservoir. The studies by Kupferberg *et al.* (2009) and Idris and Amba (2011) demonstrated the influence of climatic factors on parasite outbreaks. The outbreak of *L. cyprinacea* in the South Fork Eel River was associated with periods of warm water temperatures, declining discharge and shrinking pool sizes, conditions which are typical for infestations on fish in other rivers (Kupferberg *et al.*, 2009). Idris and Amba (2011) showed that temperature fluctuations during monsoon season may contribute to parasitic outbreaks. Dissolved oxygen was significantly correlated with parasite intensity and *DO* levels increased during the turnover period (complete mixing of the water body). Thus, our results are in good agreement with Barson *et al.* (2008b), and increases in *DO* levels coincided with an increase in parasite intensity; high levels of *DO* content in the water are considered desirable for the proliferation of *L. cyprinacea*. In addition to the fluctuating environmental factors, host densities (fish populations) were high in the cool, dry season as most fish species were coming out of the breeding season in Malilangwe reservoir (Tatenda Dalu, *personal observation*).

In *Oreochromis mossambiccus*, for example, the prevalence and mean intensity in the Malilangwe Reservoir in 2007 were 100% and 149 (14–419), respectively (Barson *et al*., 2008b) and in the present study, the mean intensity in all the study months was smaller than the previous study: this could be attributed to the sampling times. Barson *et al*. (2008b) carried out their study in October to December (hot, wet season) and this can be assumed to be the greatest peak season for the parasite in the reservoir and coincides with the first rains of the season, while the current study was carried out in February to October 2011, mostly the dry season (no rain) and the peak observed in May to July could be associated with reservoir hydrological changes.

The effect of the parasite on fish populations could therefore cascade to other biota as the parasite is showing no sign of declining. More studies on host parasites need to be investigated as Kupferberg *et al.* (2009) showed that *L. cyprinacea* can have devastating impacts on amphibian populations such as morphological abnormalities compared with the uninfested individuals. A major flood like the one experienced in 2000 (Cyclone Eline) is required to help flush out the reservoir and reduce the *L. cyprinacea* infestations. Although the infected fish are generally considered safe to eat (Barson *et al*., 2008b), heavily infested ones are unsightly for anglers who patronise the dam as a touristic and recreational activity.

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