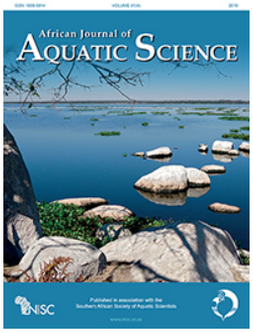

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Short Note

Parasites of fishes in the recently inundated ephemeral Lake Liambezi, Namibia

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Lake Liambezi forms the periodic connection between the upper Zambezi, Kwando and Okavango rivers. A full parasitological assessment was conducted on 86 fish, representing 14 species in six families sampled in August 2011. Parasite diversity was low and dominated by species with complex life cycles involving intermediate hosts. Most prevalent were larval nematodes (*Contracaecum* sp.) infecting 12 and *Trypanasoma* sp. infecting nine of the 14 host species. The intra-erythrocytic parasite *Babesiosoma mariae* was found in the blood of *Coptodon rendalli* and *Oreochromis andersonii* with prevalence of 50% and 60%, respectively. The host-specific monogenean *Annulotrema hepseti* was recorded only from *H. cuvieri* with a prevalence of 100%. Notable absences were the copepod and branchiuran parasites that have direct lifecycles and usually occur in high prevalence and abundance in the region. Because parasites with direct life cycles can only be transported into the lake on the host fish, their absence suggests limited immigration of infected fishes into the lake. This suggests that internal recruitment dominates over immigration in the fish population dynamics in Lake Liambezi.

Keywords: *Annulotrema hepseti*, *Babesiosoma mariae*, *Contracaecum*, *Trypanosoma*

The upper Zambezi floodplain and Okavango ecoregions are important in providing livelihoods through a variety of ecosystem services to thousands of people (Tweddle 2010). Pressures on these systems include habitat degradation, overfishing and the introduction of alien fishes and pathogens (Tweddle 2010; McHugh et al. 2014; Tweddle et al. 2015). Although isolated from the Lower Zambezi by the Victoria Falls, which forms an impassable barrier for fishes (Abell et al. 2008), the Zambezi, Kwando and Okavango rivers are periodically connected via Lake Liambezi (17°52.942′ S, 24°23.706′ E; Figure 1), a large (300 km^2), shallow (average depth when full = 3.5 m), ephemeral lake in Namibia that undergoes cyclical phases of flooding and drying (Peel et al. 2015). Understanding such connections is important for understanding not only the biogeography of the region, but also the risks to transfer of alien organisms between these rivers.

Lake Liambezi is an ephemeral lake that is connected to the upper Zambezi River via its Chobe River tributary, and during high flood years, via the Bukalo Channel (Peel et al. 2015). The Kwando River flows into the Linyati wetlands and into the Linyati River, which flows eastward into the lake, and also occasionally connects to the Okavango River via the Selinda spillway (see Tweddle 2010; Peel et al. 2015). After a series of drying and inundation phases between 1942 and 1985, the lake dried up completely in 1986. It only filled again during a major flood in April 2009 and rainy season inflows in 2010 and 2011 (Peel et al. 2015). During the most recent inundation phase (2009–2011), 49 fish species colonised the lake and a 3 000 t y^{-1} artisanal fishery was established (Peel et al. 2015).

Understanding the ecology of Lake Liambezi is therefore not only important in understanding fish distributions and biogeography, but also contributes towards better understanding the drivers for ecosystem services that this lake provides through fisheries. Of particular interest is understanding whether fish stocks in the lake are dependent on external (immigration) or internally driven (establishment) processes.

Fish parasites, a natural part of aquatic ecosystems, are commonly used as biological indicators, tags or markers to provide information on various aspects of host biology, including population biology and migrations (Williams et al. 1992; Adlard et al. 2015). This is because, in order to become infected, a host organism must first be exposed to either the environment, vector or intermediate host of the parasite. For this reason, a full parasitological assessment was conducted on 86 fish, representing 14 species in six families, sampled from the lake using gillnets, electrofishing and angling in August 2011 (Table 1). The aim of this assessment was to test the hypothesis that parasite diversity and abundance in/on fishes that had colonised the recently flooded lake was representative of those described from the potential source populations in the Okavango, Kwando and upper Zambezi River systems (see Table 2). Accepting the

hypothesis would infer that parasites recruited into the lake together with their hosts and consequently fish populations in the lake are dependent on immigration, while rejecting the hypothesis would infer that some parasites were unable to colonise the lake and that fish populations are driven by internal recruitment processes.

The sample of fish used for the parasitological assessment was also assessed for the presence of epizootic ulcerative syndrome (EUS), the results of which have been published (McHugh et al. 2014). Live fish were transferred to a field laboratory, identified to species level using keys provided by Skelton (2001), measured and inspected for external parasites. Following this preliminary examination, blood was drawn from the caudal vein, using a 21-gauge needle and 1-ml syringe, transferred onto microscope slides (blood smear), fixed in absolute methanol and stained with Giemsa's stain following Smit et al. (2003, 2004). Fish were then sacrificed by severing the spinal cord anterior to the dorsal fin and were macroscopically examined internally for parasites. Any parasites found were removed and preserved in 70% ethanol for later identification.

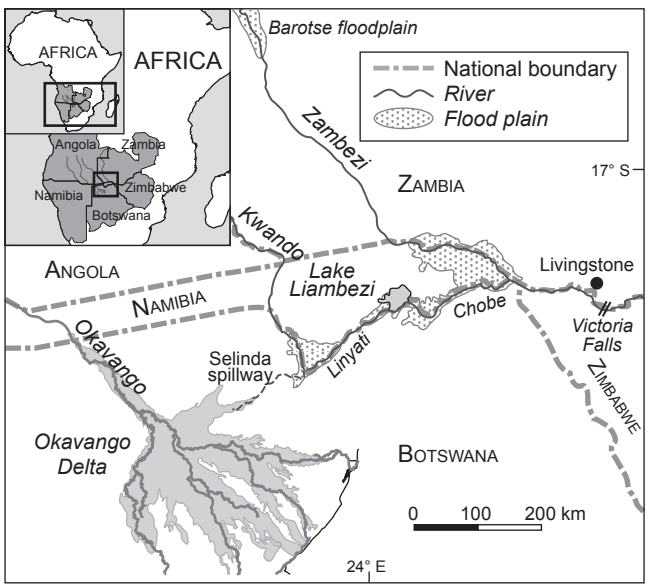

Figure 1: Map of the Zambezi Region showing the Zambezi, Kwando and Okavango rivers that periodically connect via the Chobe River, Lake Liambezi, the Linyati River and the Selinda spillway

Subsequent assessment of parasite diversity and prevalence demonstrated that few fish parasites appear to have colonised the lake. Only four taxa, the blood protozoans *Trypanasoma* sp. and *Babesiosoma mariae*, the larval nematode *Contracaecum* sp., and the monogenean *Annulotrema hepseti*, were recorded (Table 1). The most prevalent parasites were the nematodes *Contracaecum* sp. infecting 12 of the 14 host species and 73% of all fish sampled and the *Trypanasoma* sp. infecting nine of the 14 host species and 33% of all fish sampled (see Table 2). The intra-erythrocytic parasite *Babesiosoma mariae* was found in the blood of the cichlids *Coptodon rendalli* and *Oreochromis andersonii* with a prevalence of 50% and 60%, respectively. The host-specific monogenean *Annulotrema hepseti* was recorded only from *H. cuvieri* with a prevalence of 100% (n = six hosts).

Voucher specimens of the various parasites collected were deposited in the parasite collection of the National Museum, Bloemfontein, South Africa [*Contracaecum* sp. infecting *C. gariepinus* (PNMBP 416); *Trypanosoma* sp. infecting *C. gariepinus* (PNMBP 417); *Babesiosoma mariae* infecting *Coptodon rendalli* (PNMBP 418); and *Annulotrema hepseti* in *H. cuvieri* (PNMBP 419)].

Table 1: Host identity, number (n), mean ± standard deviation length (mm) and prevalence of *Trypanosoma* sp. (Tryp.), *Contracaecum* sp. (Cont.), *Babesiosoma mariae* (Babe.) and *Annulotrema hepseti* (Annu.) sampled from Lake Liambezi, Namibia, in August 2011; *prevalence based on the examination of a single specimen

Host	Host		Parasite prevalence (%)			
	n	Length (mm)	Tryp.	Cont.	Babe.	Annu.
Cichlidae						
Coptodon rendalli	4	148 ± 64 (84–211)	100	100	50	0
Oreochromis andersonii	5	183 ± 72 (100–279)	40	100	60	0
Oreochromis macrochir	4	218 ± 95 (80–291)	75	100	0	0
Sargochromis codringtonii	7	139 ± 11 (125–154)	85	100	0	0
Serranochromis macrocephalus	8	106 ± 6 (101–115)	25	100	0	0
Serranochromis robustus	3	240 ± 32 (211–274)	66	100	0	0
Tilapia sparrmanii	3	98 ± 6 (90–104)	100	33	0	0
Clariidae						
Clarias gariepinus	1	325	100*	100*	0*	0*
Clarias ngamensis	5	438 ± 12 (425–455)	100	100	0	0
Clarias theodorae	1	239	0*	0*	0*	0*
Hepsetidae						
Hepsetus odoe	6	245 ± 52 (194–345)	0	100	0	100
Mochokidae						
Synodontis nigromaculatus	15	156 ± 17 (125–185)	0	53	0	0
Mormyridae						
Marcusenius altisambesi	10	182 ± 18 (154–208)	0	0	0	0
Schilbeidae						
Schilbe intermedius	14	215 ± 24 (195–251)	0	78	0	0

Trypanosoma sp. and *Contracaecum* sp. demonstrated low host specificity and were therefore present in most of the fish species sampled. The high prevalence of infection by the trypanosomes may be a result of its vector (leeches, according to Hayes et al. 2006) occurring in higher abundances in standing water with large amounts of aquatic vegetation, as is found in Lake Liambezi (Mann 1955). *Contracaecum* spp. also do not have a direct life cycle and so have to make use of primary hosts, such as aquatic crustaceans or snails, as well as definitive hosts, such as fish-eating birds (Barson and Marshall 2004). Leeches are highly mobile organisms (van As et al. 2012), snails have been known to be transported to new areas attached to the bills or legs of birds and even in the gut of birds and fishes (Alonso and Castro-Diez 2008), and crustacean zooplankton organisms are transported in the water column (van As et al. 2012) or hatch from resting or dormant eggs that reside and persist in the sediment through desiccation and rapidly re-establish populations following inundation (Hairston et al. 1995). It is possible that the high prevalence of trypanosomes and *Contracaecum* larvae in Lake Liambezi is a result of immigration and establishment of vector, intermediate and definitive host populations.

In comparison with a checklist of parasites from the potential source populations (Table 2), the parasite diversity found in Lake Liambezi in 2011 was relatively depauperate. The most notably absent species were copepod and branchiuran parasites that have direct lifecycles and are either not host specific (e.g. *Dolops ranarum*) or highly host specific (e.g. various species of *Chonopeltis* and *Argulus*). These crustaceans, especially *D. ranarum*, occur in high prevalence and abundance in the region (van As and van As 2015), but can only colonise new areas if they are brought in by a fish host. Their absence from Lake Liambezi

Table 2: Checklist of fish parasites from the Upper Zambezi Floodplain and Okavango ecoregions (source literature: Baker 1960; Basson and van As 1989, 2002; Christison et al. 2005; Davies et al. 2005; Fryer 1968; Moravec and van As 2001, 2015a, 2015b, 2105c, 2015d; Oldewage and Avenant-Oldewage 1993; Reed et al. 2002, 2003; Smit et al. 2000, 2003, 2004; van As 1992; van As and Basson 1984, 1992; van As and van As 1996, 1999, 2015); * denotes species from which the parasite was sampled during the current study

Parasite	Known host species
Dactylosomatidae	
Babesiosoma mariae	*Coptodon rendalli**, *Oreochromis andersonii**
Trypanosomatidae	
Trypanosoma sp.	*C. rendalli**, *O. andersonii**, *Oreochromis macrochir**, *Sargochromis codringtonii**, *Serranochromis macrocephalus**, *Serranochromis robustus**, *Tilapia sparrmanii**, *Clarias gariepinus**, *Clarias ngamensis**, *Schilbe intermedius*
Myxozoa	
Myxobolus gariepinus	*C. gariepinus*
Myxobolus camerounensis	*O. andersonii*
Myxobolus africanus	*Hepsetus cuvieri*
Myxobolus cf. *tilapia*	*C. rendalli*
Nematoda	
Camallanus ctenopomae	*Ctenopoma* sp.
Cithariniella longicaudata	*S. intermedius*
Contracaecum sp.	*C. rendalli**, *O. andersonii**, *O. macrochir**, *S. codringtonii**, *S. macrocephalus**, *S. robustus**, *T. sparrmanii**, *C. gariepinus**, *C. ngamensis**, *H. cuvieri**, *Synodontis nigromaculatus**, *S. intermedius**
Falcaustra similis	*S. nigromaculatus*, *S. vanderwaali*, *S. intermedius*
Paracamallanus cyathopharynx	*C. stappersi*, *C. theodorae*, *C. gariepinus*
Philometroides africanus	*H. cuvieri*
Procamallanus daleneae	*Synodontis vanderwaali*
Procamallanus laeviconchus	*S. nigromaculatus*, *Synodontis thamalakanensis*, *S. intermedius*
Procamallanus pseudolaeviconchus	*C. stappersi*, *C. theodorae*
Procamallanus serranochromis	*Serranochromis angusticeps*, *S. macrocephalus*, *S. robustus*
Procamallanus spiralis	*C. stappersi*, *C. theodorae*, *H. cuvieri*
Spinitectus polli	*Synodontis nigromaculatus*
Synodontisia annulata	*S. intermedius*
Monogenea	
Annulotrema hepseti	*H. cuvieri**
Branchiura	
Argulus ambloplites	*C. gariepinus*
Argulus cunningtoni	*C. gariepinus*, *S. macrocephalus*
Chonopeltis koki	*Labeo cylindricus*
Dolops ranarum	24 host species (see Table 2 in van As and van As 2015)
Chonopeltis liversedgei	*M. lacerda*
Chonopeltis lisiki	*Synodontis leopardinus*, *S. macrostigma*, *S. nigromaculatus*, *S. thamakanensis*, *S. vanderwaali*
Copepoda	
Ergasilus mirabilis	*Marcusenius altisambesi*, *S. intermedius*
Lernaea barnimiana	*O. macrochir*, *T. sparrmanii*
Lamproglena clariae	*C. gariepinus*

during the current study suggests limited immigration of infected fishes into the lake and therefore that internal recruitment most probably dominates over immigration in the fish population dynamics in Lake Liambezi.

Because the study was conducted in 2011, only two years after the initial filling in 2009, future research on the development of parasite communities in the lake would provide interesting insights into the establishment rates of fish parasites.

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