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ORIGINAL PAPER

Parasite fauna of farmed Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) in Uganda

Peter Akoll · Robert Konecny · Wilson W. Mwanja · Juliet K. Nattabi · Catherine Agoe · Fritz Schiemer

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Abstract An intensive parasite survey was conducted in 2008 to better understand the parasite fauna occurrence, distribution and diversity in the commercial aquaculture fish species in Uganda. A total of 265 fish collected from hatcheries and grow-out systems were examined for parasites using routine parasitological techniques. The survey yielded 17 parasite species: 11 from *Oreochromis niloticus* and ten from *Clarias gariepinus*. Four parasites—*Amirthalingamia macracantha*, *Monobothrioides* sp., *Zoogonoides* sp. and a member of the family Amphilinidae—were recorded for the first time in the country. The parasite diversity was similar between hosts; however, *O. niloticus* was dominated by free-living stage-transmitted parasites in lower numbers, whereas both trophically and free-living stage-transmitted parasites were equally represented in *C. gariepinus* in relatively high intensities. The patterns in parasite numbers and composition in the two hosts reflect differences in fish habitat use and diet. A shift in parasite composition from monoxenous species-dominated communities in small-sized fish to heteroxenous in large fishes was recorded in both hosts. This was linked to ontogenetic feeding changes and prolonged exposure to parasites. Polyculture systems showed no effect on parasite intensity and composition. The gills were highly parasitized, mainly by protozoans and monogeneans. Generally, the occurrence and diversity of parasites in these fish species highlight the likelihood of disease outbreak in the proposed intensive aquaculture systems. This calls for raising awareness in fish health management among potential farmers, service providers and researchers.

P. Akoll (✉) · J. K. Nattabi · C. Agoe
Department of Biology, School of Biological Science,
Makerere University,
P.O. Box 7062, Kampala, Uganda
e-mail: pakoll@zoology.mak.ac.ug

P. Akoll
e-mail: akollp@gmail.com

P. Akoll · R. Konecny · F. Schiemer
Department of Limnology, University of Vienna,
Althanstrasse 14,
1090 Vienna, Austria

R. Konecny
Environment Agency Austria,
Spittelauer Lände 5,
1090 Vienna, Austria

W. W. Mwanja
Department of Fisheries Resources,
Ministry of Agriculture Animal Industry and Fisheries,
P.O. Box 4 Entebbe, Uganda

Introduction

Fish farming in Uganda is expanding rapidly, following dwindling of wild stocks and intensive promotion of aquaculture countrywide (MAAIF 2004; UBOS 2008). Accordingly, the country's fish production has increased from 32,000 tonnes in 1997 to 51,000 tonnes in 2007, mainly of tilapia, *Oreochromis niloticus*, and catfish, *Clarias gariepinus* (DFRU 2008). In line with the increasing aquaculture activities, substantial information has been generated on aquaculture-related subjects in the country. An exception is fish diseases. Outbreaks of disease, however, constrain sustainable aquaculture production unless comprehensive management strategies are in place (Subasinghe et al. 2001; Bondad-Reantaso et al. 2005). Preliminary investigations into disease outbreaks in fish farming systems have reported a number of conditions resulting in mortality (Akoll 2005; Florio et al. 2009). Scarcity of

information on aetiological agents hampers the development of cost-effective and ecologically sustainable strategies for disease control (Subasinghe et al. 2001; Bondad-Reantaso et al. 2005). With high fish stocking densities under commercial fish production, parasite outbreaks will undoubtedly increase (Michel 1989; Meyer 1991; Bondad-Reantaso et al. 2005). The crowding effects and frequent water deterioration provide ideal conditions for the transmission and proliferation of parasites, particularly for species with direct life cycles. Moreover, it is a common practice to polyculture *O. niloticus* with *C. gariepinus* in an attempt to control the proliferative reproduction of tilapia in Uganda. However, variation in host specificity between and within parasite groups, especially monogeneans, polyculture pose a threat of parasite cross-transmission (Sasal et al. 1999; Bakke et al. 2002; Cribb et al. 2002). Due to differences in host immunity, infection with parasites from different hosts may inflict strong pathologies and possibilities of mortalities. Therefore, information on the occurrence, intensity and prevalence of parasites in culture systems and the possible cross-transmission in polyculture facilities is necessary for the development of appropriate disease prevention and control measures.

The Government of Uganda is currently preparing a national strategic framework on fish health management to harmonise disease control and prevention options and to control usage of chemicals in aquatic systems. Amongst the essential requirements for the preparation of the national strategy is a list of pathogens upon which a comprehensive health management scheme can be formulated. The appreciable information on fish parasites from the major lakes and rivers is summarised in Khalil (1971) and Paperna (1996). This has provided an insight into the fauna in natural water bodies, which supply water to fish farming facilities. Nonetheless, this list requires updates on the occurrence and diversity of pathogens in target fish species. Moreover, differences in host ecology created by the farming systems may alter the survival and pathogenicity of parasites (Marcogliese 2001; Lafferty 2008). As such, system-specific information is more reliable in developing comprehensive disease management strategies.

This survey was designed to provide an insight on the occurrence and distribution and contribute to the national inventory of parasites infesting the main cultivated and commercial fishes (*O. niloticus* and *C. gariepinus*) in Uganda. The specific objectives of the survey are to (1) determine the parasites' diversity and their infection intensity and prevalence in *O. niloticus* and *C. gariepinus*, (2) describe the change in parasite species composition with fish size, (3) determine the effect of polyculturing on parasite diversity and, (4) determine and relate the most parasitized organ to fish health.

Methods and materials

Study site and sample collection

Aquaculture in Uganda is relatively developed along the shore of Lake Victoria, also called Lake Victoria crescent. Twenty-five (25) fish farms, five from each of the districts of Masaka, Mpigi/Mityana, Wakiso, Mukono and Kampala within the crescent (Fig. 1), were surveyed for parasites. The sampling was done within 1 month of July 2008 to understand the spatial distribution of parasites and avoid temporal effects on parasite burden. Although, all parasites may not be present during this sampling period, the survey provides the first snapshot but detailed information on parasite diversity and distribution in the country. The farms

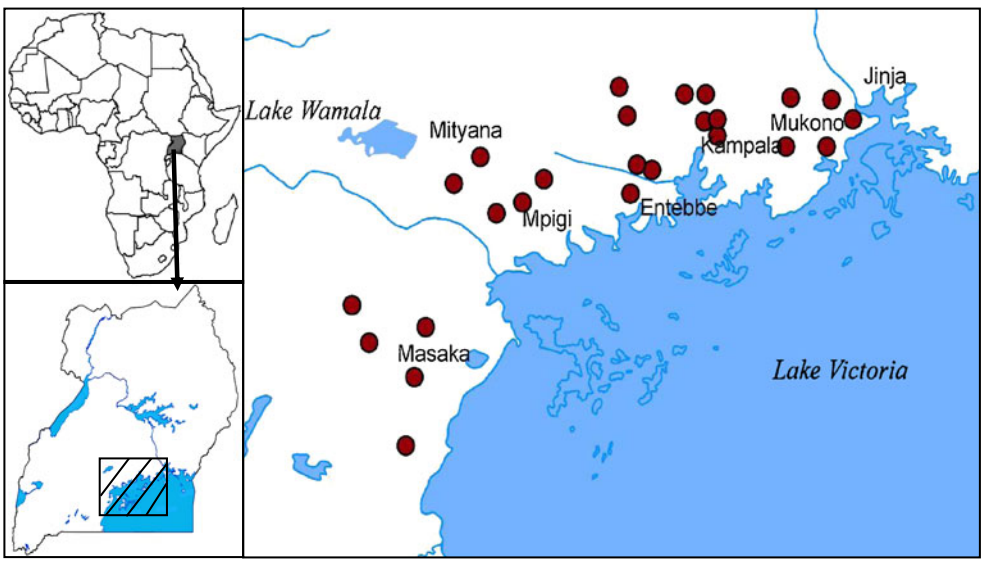

Fig. 1 The location of sampling sites in Uganda, study area (▨) and sampling points (●)

consisted of two specialised hatcheries for tilapia, eight for catfish. Three farms were grow-outs for tilapia only, seven polycultured tilapia and catfish, and five farmed both species separately. Catfish hatching was done artificially in concrete tanks and incubation under controlled water conditions (aerated and temperature-maintained between 25°C and 28°C) with water supplied with groundwater. Three or 4 weeks post-hatching, the fry were transferred to earthen ponds supplied intermittently with surface water from neighbouring streams, filtered through a fine mesh (undisclosed size but able to retain clay particles). During this time, the fish were fed on dry, protein-rich feeds and some zooplankton until they were sold. Tilapia fry production was done naturally in "hatching ponds". Twenty-one days after mixing males and females, the ponds were seined to retrieve the fry and maintained in concrete tanks supplied with surface water for 2 weeks. The fry were transferred to earthen ponds thereafter or sold to grow-out farmers. The size of grow-out ponds ranged from 450 to 1,000 m^2, and the ponds were stocked with fry (five fish per square metre and at the ratio of 3:1 for tilapia to catfish in polyculture). The fry for stocking originated mainly from the hatcheries surveyed, though some grow-out farmers obtained additional fry from other hatcheries within the region. Temperature, dissolved oxygen, conductivity and pH were measured during the survey, but these parameters did not significantly differ across farms visited, except for conductivity. During the survey, random samples of at least ten fish were collected from each farm. A total of 265 specimens, consisting of *C. gariepinus* (n=125) and *O. niloticus* (n=140) were examined. The fish's total length ranged from 4 to 24 cm and 5 to 40 cm in total length (TL), and total weight was from <1 to 450 g and <1 to 700 g for tilapia and catfish, respectively.

Fish examination and parasite collection

In the laboratory, small fish (≤3 cm) were squashed between slides and examined under a light microscope for ectoparasites, encysted and free endohelminths. For fish specimens with TL from 4 to 10 cm, whole body examinations were done under a dissecting microscope. Thereafter, smears from the skin and gills were examined for ectoparasites. The fish were then dissected using a needle to expose internal organs, and identifiable tissues were examined for endoparasites. In fish specimens larger than 10 cm, mucus from skin scrapings and gill chips were examined for ectoparasites before dissections. The intestines and pieces of different organs (e.g., kidney and liver) were also examined. All individual parasites observed were counted, fixed and sent for identification to the Department of Veterinary Public Health and Animal Pathology, Faculty of Veterinary Medicine, University of Bologna, Italy. Monogeneans were identified from Institute of Aquaculture, University of Stirling, Scotland.

Data analysis

Parasite diversity was determined at component community level (the total number of parasite species recorded in the entire sample for each fish species) and infracommunity level (the number of parasite species recorded on each host individual). At the component community level, we determined the component species according to Kennedy (1993), the total number of parasite species, the Shannon–Wiener Index (H') and evenness (E), and the Berger–Parker Dominance Index (d). Trichodinids were not included in the calculation of the Shannon–Wiener, evenness and Berger–Parker dominance indices because not the entire population was counted. At the infracommunity level, the maximum and average infracommunity richness was calculated. Differences in the average infracommunity richness between hosts were determined using the t test. The parasites were categorised into free-living stage-transmitted parasites (FTP) for species reaching their hosts via free-living stages such as cercariae, free-swimming larvae or adults and oncomericidia and trophically transmitted parasites (TTP) for the parasite reaches fish through ingestion of intermediate hosts. Parasite prevalence, mean intensity and mean abundance were determined according to Bush et al. (1997). The relationship between size and parasite intensity was examined using Pearson correlation coefficients. Only parasite species occurring on more than five fish specimens were included in the determination of the host size–parasite intensity relationship.

Results

Parasite diversity, prevalence and intensity

Overall, of the 265 specimens examined, 89% (124/140) of the *O. niloticus* specimens and 54% (68/125) of the *C. gariepinus* specimens were infested with at least one parasite. The parasite diversity indices did not differ significantly between the two fish species, except for average infracommunity richness, which was higher in *O. niloticus* than *C. gariepinus* (t test, p<0.05, Table 1). Despite the similarity in parasite diversity, *O. niloticus* was composed of 72.7% (8/11) FTP, namely, trichodinids, *Myxobolus* sp., *Ichthyobodo* sp., *Cichlidogyrus* spp. (*Cichlidogyrus sclerosus* and *Cichlidogyrus tilapiae*), *Macrogyrodactylus congolensis*, *Bolbophorus* sp., *Clinostomum cutaneum* and *Lamproglena* sp. and 27.3% (3/11) TTP (*Amirthalingamia macracantha*, *Acanthosentis* (*Acanthogyrus) tilapiae* and Camallanidae larvae). On the other

Table 1 Component and infracommunity structure of parasites from *O. niloticus* and *C. gariepinus*

Diversity parameter	*O. niloticus* (n=140)	*C. gariepinus* (n=128)
Component community level		
Total number of species	11	10
Component species richness (≥10%)	7	5
Shannon index (H')	1.475	1.448
Evenness (E)	0.615	0.629
Berger–Parker index (d)	0.402	0.474
Dominant species	*Amirthalingamia macracantha*	*Monobothrioides* sp.
Infracommunity level		
Maximum infracommunity richness	6	5
Average infracommunity richness	2.53	1.92

hand, *C. gariepinus* was parasitized with ten species composed of 50% FTP, including, trichodinids, *Epistylis* sp., *M. congolensis*, *Cichlidogyrus* sp. and *Ornithodiplostomum* sp. and 50% TTP, namely, *Zoogonoides* sp., *Monobothrioides* sp., Amphilinidae, Camallanidae larvae and Anisakidae larvae. Among the parasites recorded, four species—*Cichlidogyrus* sp., *M. congolensis*, trichodinids and Camallanidae—were recorded infesting both fish species. Four species, including *A. macracantha* from *O. niloticus* and *Monobothrioides* sp., unidentified trematodes tentatively determined as *Zoogonoides* sp. and an unidentified monozoic cestode, a representative of the family Amphilinidae from *C. gariepinus* are reported for the first time in Uganda.

The prevalence and mean intensity (and mean abundance) of parasites found in *O. niloticus* and *C. gariepinus* are shown in Table 2. Trichodinids were the most prevalent parasite from both fish species, followed by the monogeneans. With regard to intensity, 18.2% (2/11) of the parasites recorded from *O. niloticus* occurred with a mean intensity of greater than or equal to five individuals per fish. These were *A. macracantha* (11 parasites per fish) and the trichodinids (8.9 parasites per fish). In contrast, 50% of the parasites recorded from *C. gariepinus* occurred with a mean intensity of greater than or equal to five parasites per fish. The community was dominated by the Amphilinidae, with a mean intensity of 264 parasites per fish, followed by *Monobothrioides* sp. (68.2 parasites per fish); *Ornithodiplostomum* sp. (13 parasites per fish), anisakids (six parasites per fish) and trichodinids (five parasites per fish). The mean abundance followed a similar pattern as mean intensity.

Host length–parasite relationship

The fry in the hatcheries were infested exclusively by monoxenous parasites, including the trichodinids and monogeneans (Table 2). The prevalences of trichodinids and *M. congolensis* in *C. gariepinus* were 83.7% and 11.6%, and the mean intensities were 5.5 and 2.4 parasites per fish, respectively. In *O. niloticus*, the prevalences of trichodinids and *Cichlidogyrus* sp. were 80.3% and 50%, and the mean intensities were 5.7 and 6.6 parasites per fish, respectively. From the grow-out systems where a wide range of fish sizes were present, the intensities of monoxenous parasites (trichodinids and monogeneans) significantly decreased with fish size, whereas the intensity of heteroxenous parasites (cestodes, digeneans, acanthocephalans and nematodes) increased with size. The trends of the host size–infection relationships are demonstrated by trichodinids and *A. macracantha* from *O. niloticus* (Fig. 2a) and by trichodinids and *Monobothrioides* sp. from *C. gariepinus* (Fig. 2b).

Parasites in polyculture

The *C. gariepinus* and *O. niloticus* specimens collected from polyculture systems were infested with *Cichlidogyrus* sp. and *M. congolensis*, respectively. The prevalence and mean intensities were very low: *Cichlidogyrus* sp. occurred on the gills of one specimen of *C. gariepinus*, while *M. congolensis* occurred on the gills of two *O. niloticus* specimens. Besides, Trichodinids occurred on both fish species from polyculture systems.

Infected organs

Table 2 shows the fish organs that were infected. Most organs examined were parasitized with at least one parasite. In *O. niloticus*, the gills harboured seven species, dominated by the monoxenous species (protozoans and monogeneans). Six species were recovered from the skin (integument) and three from the intestine. In *C. gariepinus*, four parasite species were recorded on the gills and skin, also dominated by monoxenous species; five from the intestines and one from the body cavity. Trematodes were the most widely distributed parasitic group. The monogenean *Cichlidogyrus* sp. were restricted to the gills of *O.*

Table 2 The infected organs, TP, inf, prevalence (percent), MI, MA and I_{max} of parasites from *O. niloticus* and *C. gariepinus*

Parasites recorded	Organ infected	*O. niloticus* (*n*=140)					*C. gariepinus* (*n*=128)				
		TP (inf)	(Percent)	MI	MA	I_{max}	TP (inf)	(Percent)	MI	MA	I_{max}
Protozoa											
Trichodinids	Integument/gills	795 (89)	63.6	8.9	5.7	70	531 (103)	83.1	5.2	4.3	17
Myxobolus sp.	Integument/gills	5 (5)	3.6	1.0	0.04	1	–	–	–	–	–
Ichthyobodo sp.	Gills	5 (2)	1.4	2.5	0.04	4	–	–	–	–	–
Epistylis sp.	Gills	–	–	–	–	–	10 (3)	2.4	3.3	0.1	5
Monogenea											
Cichlidogyrus sp.	Integument/gills	158 (73)	52.1	2.2	1.1	8	2 (1)	0.8	2.0	0.02	2
M. congolensis	Integument/gills	2 (2)	1.4	1.0	0.01	1	130 (39)	31.5	3.3	1.0	14
Digenea											
Bolbophorus sp.	Integument/gills	55 (30)	21.4	1.8	0.4	3	–	–	–	–	–
Clinostomum cutaneum	Integument	69 (32)	22.9	2.2	0.5	5	–	–	–	–	–
Ornithodiplostomum sp.	Body cavity	–	–	–	–	–	525 (38)	30.6	13.8	4.2	200
Zoogonoides sp.	Intestine	–	–	–	–	–	2 (2)	1.6	1.0	0.02	1
Cestoda											
A. macracantha	Intestine	679 (62)	44.3	11.0	4.9	29	–	–	–	–	–
Monobothrioides sp.	Intestine	–	–	–	–	–	1,977 (29)	23.4	68.2	15.9	157
Amphilinidae	Intestine	–	–	–	–	–	793 (3)	2.4	264.3	6.4	300
Acanthocephala											
Acanthogyrus (*A*) *tilapiae*	Intestine	174 (44)	31.4	4.0	1.2	10	–	–	–	–	–
Nematoda											
Camallanidae	Intestine	34 (14)	10.0	2.4	0.2	7	81 (21)	16.9	3.9	0.7	15
Anisakid (*contracaecum* sp.)	Intestine	–	–	–	–	–	19 (3)	2.4	6.3	0.2	12
Crustacea											
Lamproglena sp.	Gills	3 (2)	1.4	1.5	0.02	2	–	–	–	–	–

TP total number of parasites, *inf* number of infested fish, *MI* mean intensity, *MA* mean abundance, I_{max} maximum infection intensity of parasites

niloticus but also occurred on the skin of two *C. gariepinus* hosts. Digeneans such as *Clinostomum* sp. were embedded in the skin, whereas *Bolbophorus* sp. (black spots) occurred both in the skin (21%) and on the gills (10%) in *O. niloticus*. *Ornithodiplostomum* sp. occurred in the viscera, and *Zoogonoides* sp. was found in the intestines of *C. gariepinus*. The cestodes, acanthocephalans and nematodes were all restricted to the intestines of the two fish species.

Discussion

Parasitic infections can be devastating in farmed organisms than in wild populations because of stressful conditions linked to crowding and frequent water quality deterioration (Michel 1989; Meyer 1991; Bondad-Reantaso et al. 2005). The control and prevention of disease outbreaks rely on knowledge about the aetiology (Subasinghe et al. 2001; Bondad-Reantaso et al. 2005). Understanding the occurrence, distribution and compositions of the parasite communities in aquaculture systems is thus important when planning disease management strategies (Subasinghe et al. 2001). This paper is the first to report on the parasite fauna of *O. niloticus* and *C. gariepinus*, the commercially cultivated fish species in Uganda. The survey found a wide spectrum of parasites in *O. niloticus* and *C. gariepinus* distributed throughout the studied area. The wide distribution reflected the indiscriminate movement of fish from hatcheries to grow-out systems. It also points to the obtainment of unscreened parent stocks from common sources: Lakes Victoria, Kyoga and Albert (Mwanja 2006). This uncontrolled movement of fish reflects the lack of or unimplemented disease control systems. Indeed, Uganda does not have functional biosecurity control system for aquatic resources and lacks the human capacity to conduct pathogen examinations prior to movement of fish resources. The successful establishment and subsequent persistence of the introduced parasites in the area are also linked to the occurrence and wide distribution of suitable hosts throughout the Lake Victoria crescent, especially birds (Byaruhanga et al. 2001) and snails (Brown 1994). Our study highlights

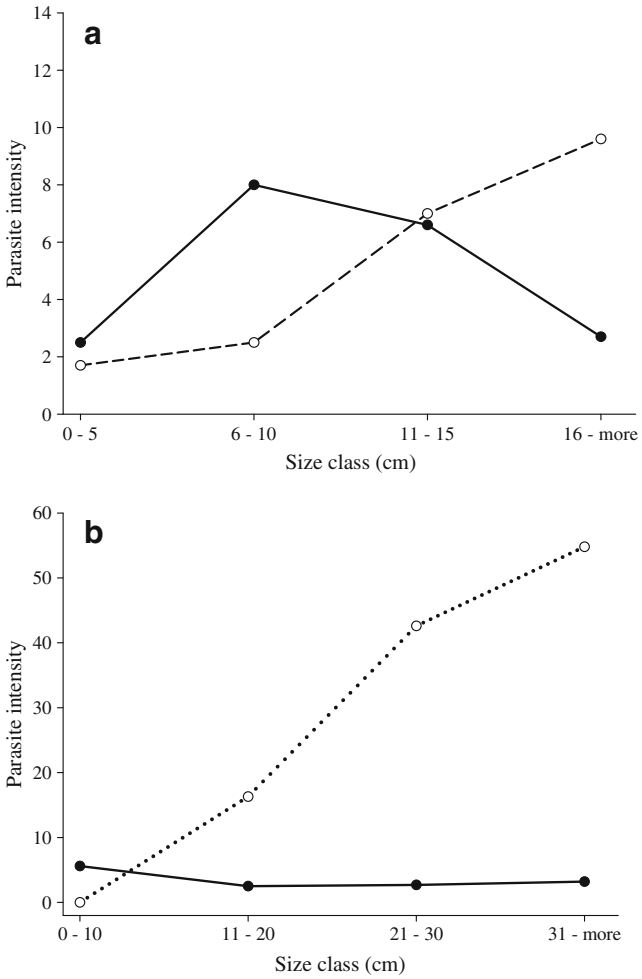

Fig. 2 The relationship between parasite intensity and size of **a** *O. niloticus* with trichodinids (*solid line*) and *A. macracantha* (*broken line*) and **b** *C. gariepinus* with trichodinids (*solid line*) and *Monobothrioides* sp. (*broken line*)

the importance of an aquatic health management framework, which guides the implementation of biosecurity systems especially in the movement of live fish for aquaculture.

The parasite diversity indices obtained in the present survey revealed that *O. niloticus* and *C. gariepinus* harboured nearly the same number of parasite species. However, the parasite community and individual numbers differed significantly. The results showed that *O. niloticus* was dominated by free-living transmitted parasites and generally at low intensities. *C. gariepinus*, in contrast, harboured equal numbers of trophically and free-living transmitted species that were present in relatively high numbers. The variation in parasite composition and numbers in the two hosts may reflect different habitat use and diet (Esch and Fernández 1993; Marcogliese 2002; Knudsen et al. 2004; Nunn et al. 2008; Mwita and Nkwengulila 2008). *O. niloticus*, for example, forms and defends territories along the shores (Philippart and Ruwet 1982; Paperna 1996). This territorial behaviour increases the proximity to and maintains continuous exposure to free-swimming stages of protozoans, crustaceans and digenetic trematodes cercariae. The strong immune resistance elicited against further invasion of ectoparasites by *O. niloticus* (Sandoval-Gio et al. 2008) could explain the low intensity recorded during the survey. With regard to endoparasites, *O. niloticus* feeds mainly on phytoplankton and macrophytes (Getachew and Fernando 1989; Dempster et al. 1993), although zooplankton and benthic organisms also contribute to the diet (Philippart and Ruwet 1982; Njiru et al. 2004; Bwanika et al. 2006; Peterson et al. 2006; Oso et al. 2006). Because zooplankton and benthic organisms act as intermediate hosts for several endohelminths, their intake exposes the fish to TTP infections. Nevertheless, the contribution of zooplankton and benthic organisms to the diet of *O. niloticus* is low, thus limiting the intake of the parasites. In contrast, *C. gariepinus* prefers marginal weedy and muddy waters (Brummett 2008) and feeds on a wide range of food items including detritus, zooplankton, insects and fish (Groenewald 1964; Mwebaza-Ndawula 1984; Brummett 2008), all of which act as intermediate hosts for several helminths. Due to its preference for a shallow muddy debris-laden habitat and its omnivorous behaviour with piscivory tendencies, *C. gariepinus* was highly exposed to both FTP and TTP infections. The omnivorous behaviour and resulting continuous intake of infected intermediate hosts led to accumulation of TTP species, culminating in high mean intensities (Esch and Fernández 1993; Marcogliese 2002). In general, the present findings support previous reports on the parasite faunas, which show that *O. niloticus* is dominated by FTP species (Bondad-Reantaso and Arthur 1990; Opara and Okon 2002; Musa et al. 2007) and that *C. gariepinus* is dominated by TTP species (Mwita and Nkwengulila 2004, 2008).

With regard to host size, the results revealed a shift in parasite composition from a monoxenous-dominated community in young fish to a heteroxenous-dominated community in large-sized fish in both fish species. The change in parasite composition was attributed to an ontogenetic feeding shift, with a prolonged exposure to intermediate hosts/infectious stages in older (larger) fish (Esch and Fernández 1993; Marcogliese 2002; Nunn et al. 2008). Although prey size of *O. niloticus* changes slightly with host age (Peterson et al. 2006), and these changes increase the exposure to TTP infections for large-sized fish. There are apparent shifts in *C. gariepinus* diet from exclusively zooplankton in larvae to large invertebrates and fish items with age (Brummett 2008). This shift from small-sized planktons to a large and broad range of food items exposes fish to a wide range of TTP species. Besides, some endoparasites e.g. *Bolbophorus* sp., *C. cutaneum*, *A.*

macracantha and Camallanidae larvae in *O. niloticus* and *Ornithodiplostomum* sp., Camallanidae larvae and Anisakidae larvae in *C. gariepinus* using fish as intermediate host. Thus, until the fish is removed from the population through predation or mortality, the parasite accumulate with fish size (age) (Esch and Fernández 1993; Mwita and Nkwengulila 2008; Nunn et al. 2008). Other parasites in final hosts such as *Zoogonoides* sp., *Monobothrioides* sp. and Amphilinidae in *C. gariepinus* also accumulate due to continuous and prolonged exposure to infected intermediate hosts. Although intraspecific competition can inhibit accumulation (Esch and Fernández 1993), this could be ascertained during the present study.

The survey found that polyculture systems did not necessarily facilitate cross infection of parasites. The presence of trichodinids on both species is not surprising because this group of parasites occur on a wide range of fish species due to their well-adapted attachment apparatus (Basson and Van As 1987; Van As and Basson 1992; Lom and Dykova 1992; Paperna 1996). Trichodinids here could not be identified to species level. We therefore could not affirm whether the same species occurred on both fish hosts. For monogeneans, their presence in very low prevalence and mean intensity suggests an unsuitability of the alternative host, and the occurrence may have been accidental. Although cross infections are possible, monogeneans have a high degree of host specificity because of chemical and mechanical stimuli from the host and mechanical structures of the parasite (Sasal et al. 1999; Buchmann and Lindenstrøm 2002; Bakke et al. 2002; Cribb et al. 2002).

Gills are a vital and delicate organ in fish; therefore, the presence of parasites ultimately interferes with fish respiration and ion exchange, reducing the general fish physiology and potentially causing fish death. Indeed, the parasite species found during this study, particularly the monogeneans and trichodinids, are known to cause mortalities (Ogawa 2002; Akoll 2005; Mansell et al. 2005). They can also increase susceptibility of fish to secondary infection (Busch et al 2003; Bandilla et al. 2006; Pylkkö et al. 2006; Xu et al. 2007). Co-infections, no doubt, exacerbate the risk of epizootics (Paperna 1996; Barker et al. 2002; Akoll 2005). The presence of endohelmniths should not be underestimated. These parasites may suppress fish reproductive capacities (Cowx et al. 2008), increase susceptibility to predation (Barber et al. 2000; Seppälä et al. 2005) or damage host tissues (Esch and Huffine 1973; Wabuke-Bunoti 1980; Mitchell et al. 1982; Feist and Longshaw 2008). Moreover, parasites such as clinostomatids are zoonotic and thus pose a public health threat (Chai et al. 2005; Gajadhar et al. 2006) and consumer rejection (Kabunda and Sommerville 1984).

Although most of the species found during the survey can be prevented or controlled, the associated costs may discourage farmers or even cause adverse environmental impacts. Disease should therefore be prioritised in fish development plans, and alternative parasite control and preventive measures utilising ecological information should be adopted. In this respect, ecological data on the parasites present are essential. The public also needs to be sensitised and made aware of key fish diseases, parasite transmission pathways and the impact on natural fisheries and aquaculture. Importantly, formulation and implementation of aquatic health management frameworks can help reduce the indiscriminate spread of diseases through infected fish.

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