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A comparative study of helminth parasites from the fish *Tilapia zillii* and *Oreochromis leucostictus* in Lake Naivasha and Oloidien Bay, Kenya

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Abstract

The parasitic fauna of two fish species, namely gill-netted samples of 652 *Oreochromis leucostictus* and 448 *Tilapia zillii* from Lake Naivasha and Oloidien Bay was investigated during the period from the end of October 1995 to September 1996. Five larval helminth parasites were recovered including the nematode, *Contracaecum* sp., the acanthocephalan *Polyacanthorhynchus kenyensis*, the digenetic trematode, *Clinostomum* sp. and two cestodes, *Amirthalingamia* sp. and *Cyclustera* sp. Both prevalence and intensity of the infection of these helminths increased in larger sized fish, whereas male fish were more heavily infected than females. No seasonality in infection level were observed. The health status of both fish species remained unaffected, although *O. leucostictus* from Oloidien Bay which harboured heavy infections of *Contracaecum* exhibited stuntedness and the lack of fatty deposits around the digestive caecum.

Introduction

A considerable amount of information is available worldwide on the helminth fauna of freshwater fish, especially in Europe, Russia and United States of America (Khalil, 1971), but incentives for comparable studies in Africa are lacking (Khalil, 1971; Paperna, 1980; Khalil & Polling, 1997). According to Douellou (1992), most studies on African fish parasites have been carried out in western, central and southern Africa, whereas literature from eastern and northern Africa is scanty due to the lack of personnel experienced in fish parasitology.

In Kenya, Malvestuto & Ogambo-Ongoma (1978) reported that fish parasitology has been under-investigated compared with other aspects of fish ecology. In Lake Naivasha, studies on the ecological aspects of fish have been well documented by Hyder (1970), Siddiqui (1977, 1979), Harper (1984), Aloo (1988), Harper *et al.* (1990), Muchiri (1990), Mwangi (1992) and Aloo & Dadzie (1995). However, the only reports available on fish parasites are those of Malvestuto (1975), Malvestuto & Ogambo-Ongoma (1978) and Aloo & Dezfuli (1997).

In the present study, the fish fauna of Lake Naivasha in Kenya comprises three economically important species, which have been introduced: *Oreochromis leucostictus*, *Tilapia zillii* and the largemouth bass, *Micropterus salmoides*. The riverine species *Barbus amphigrama* and the Louisianan crayfish, *Procambarus clarkii* also occur in the lake. The first three species form the backbone of a commercial fishery which has been established in Lake Naivasha for over fifty years.

The present study was therefore undertaken to analyse the helminth parasites from two tilapia species, *Oreochromis leucostictus* and *Tilapia zillii* inhabiting both the Main Lake and the Oloidien Bay of the Naivasha basin, Kenya.

Materials and methods

Study area

Lake Naivasha, which is the only freshwater body in the eastern arm of the Kenyan portion of the Rift Valley, is situated about 100 km north of Nairobi, the capital city, at an altitude of 1890 m above sea level (Litterick *et al.*, 1979). The lake has a total area of 150 km^2 and a mean depth of 6 m. The Naivasha basin is roughly circular and is made

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up of four water bodies: the Main Lake, Crescent Island Lake, the Oloidien Bay and the Sonacchi Crater Lake. The lake has always been an important ecological site in Kenya because of the diversity of flora and fauna especially avifauna in the range of vegetation zones associated with the lake and its hinterland.

The area of Lake Naivasha also has a high economic value, including the raising of export cash crops around its shores which heavily depend on lake water for irrigation. Lake Naivasha is also a focus for tourism and recreaction, which have been growing in volume ever since the first sport-fishing began in the 1920s and this was largely dependent upon the introduced largemouth bass, *Micropterus salmoides* (Harper *et al.*, 1990).

Fish sampling and parasitological procedures

Based on earlier reports of the distribution of the two tilapias in the two water bodies (Aloo, 1988), six sampling sites were established around the lake with five in the Main Lake and one at Oloidien Bay. The stations were selected on the basis of differences in physico-chemical parameters. Eight gill nets of different mesh sizes ranging from 1 to 5 inches were laid overnight at each station and the catch collected the following day. Each station was fished once a month during the period October 1995 to September 1996.

Upon removal from the nets, fish from each station were placed in plastic containers according to species. Samples of each species, which were examined for ectoparasites on removal from the nets, were transported to the laboratory where a subsample of ten fish of each species, based on sex and size, was drawn from each station. In cases where the total number of each species caught from a station was less than ten, all fish were examined. The subsampled fish were divided into 5-cm length classes and subjected to a thorough parasitological examination. The external surface including the fins, nostrils, beneath the operculum and under the scales was examined for ectoparasites. Each fish was opened up dorsoventrally, the alimentary tract was separated from the other organs and placed in a Petri dish of physiological saline where it was opened and examined for endoparasites. The liver, kidney, urinary bladder, pericardial cavity and the musculature were also examined for parasites from a total of 1100 fish, comprising 652 *O. leucostictus* and 448 *T. zillii*. Nematodes were killed in hot 70% ethyl alcohol, while acanthocephalans and cestodes were placed in a refrigerator overnight in Petri dishes containing distilled water. This caused the proboscis of the acanthocephalans and the scolex of the cestodes to extrude. Trematodes were fixed in glacial acetic acid and pressed between two slides, and preserved in 70% ethyl alcohol. Each group of parasites was classified to the species level where possible using permanent whole mounts. The effect of the parasites on the health status of the fish host was investigated from Fulton's condition factor (K-factor) with the following formula:

$$\text{K-factor} = \frac{100W}{L^3}$$

where W = weight (g) and L = length (cm).

The K-factor was then related to the number of worms in each host, relative to host size and sex. Statistical analyses included the use of two-factor ANOVA, regression analysis and Split-plot design.

Results

Oreochromis leucostictus and *Tilapia zillii* from lake Naivasha and the Oloidien Bay did not harbour any ectoparasites but both fish species hosted the larval stages of five helminths, namely: third stage larvae of *Contracaecum* sp., cystacanths of *Polyacanthorhynchus kenyensis*, cysticercoids of *Amirthalingamia* sp. and *Cyclustera* sp. and metacercariae of *Clinostomum* sp. The most prevalent and abundant parasites were *Contracaecum* sp. and *P. kenyensis*, but no seasonal variation in prevalence was observed in the two hosts ($P > 0.05$) (fig. 1). However, *O. leucostictus* was more heavily infected with *Contracaecum* sp. and *P. kenyensis* than *T. zillii.* The trematode *Clinostomum* sp. only infected *O. leucostictus*, whereas *Amirthalingamia* sp. only occurred in *T. zillii.* Cysticercoids of *Cyclustera* sp. were found in both *O. leucostictus* and *T. zillii* with a higher abundance in the latter (table 1). The parasites also infected a range of internal organs, i.e. *Contracaecum* was found free in the pericardial cavity of *O. leucostictus* but was encysted in *T. zillii.* Larval stages of *P. kenyensis* and *Cyclustera* sp. were all encysted in the liver, *Amirthalingamia* sp.

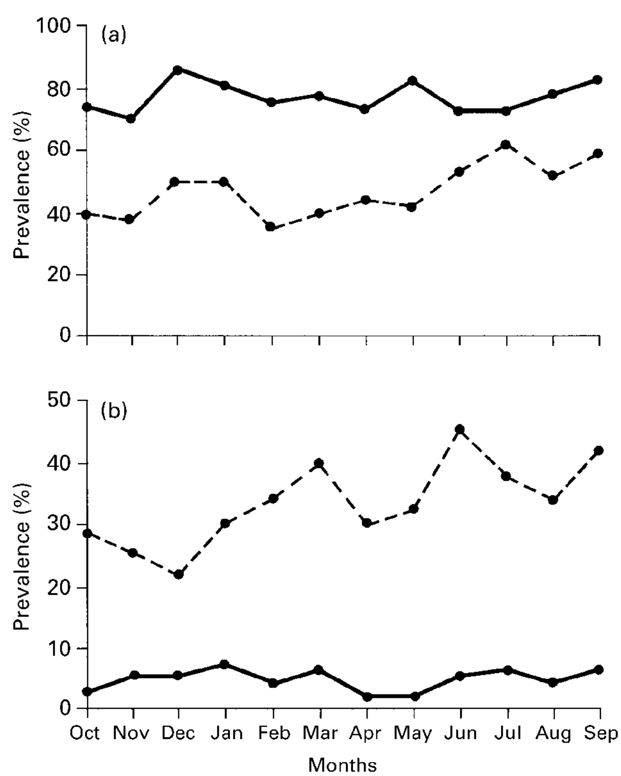

Fig. 1. Monthly prevalences of *Contracaecum* sp. (—) and *Polyacanthorhynchus kenyensis* (- - -) in (a) *Oreochromis leucostictus* and (b) *Tilapia zillii* during the period October 1995 to September 1996.

Table 1. The occurrence of helminths in *Oreochromis leucostictus* and *Tilapia zillii* from Lake Naivasha and Oloidien Bay.

Fish species	Helminth species	Site of infection	No. of fish infected (%)
Oreochromis leucostictus	*Contracaecum* sp.	Free floating in pericardial cavity	321 (49.2)
	Clinostomum sp.	Beneath operculum, pharyngeal region	42 (6.4)
n = 652	*P. kenyensis*	Encysted in liver	284 (43.5)
	Cyclustera sp.	Encysted in liver	134 (20.5)
Tilapia zillii	*Contracaecum* sp.	Encysted in pericardial cavity	9 (2.0)
	P. kenyensis	Encysted in liver	121 (27.0)
n = 448	*Amirthalingamia* sp.	Encysted in intestines	48 (10.7)
	Cyclustera sp.	Encysted in liver	158 (35.3)

n, number of fish examined %, prevalence of infection.

encysted in the intestine whilst cysts of *Clinostomum* sp. occurred either below the operculum or in the pharyngeal region.

The relationship between some parasite species and the location of sampling showed significant differences ($P < 0.001$), whereby *O. leucostictus* caught from Oloidien (mean conductivity = 1870 $\mu S\,cm^{-1}$) were more heavily infected with *Contracaecum* sp. than those from the Main Lake (mean conductivity = 450 $\mu S\,cm^{-1}$). *Tilapia zillii* from Oloidien Bay harboured low infection levels of *Contracaecum* sp. and there were no nematode infections at all from the Main Lake. The acanthocephalan, *P. kenyensis* was abundant in both fish species in the Main Lake, but low infection levels were evident in Oloidien Bay. Among the cestodes, *Amirthalingamia* sp. infected only *T. zillii* from Oloidien Bay while *Cyclustera* sp. was abundant in fish in the Bay but were found in low numbers in fish from the Main Lake. The trematode *Clinostomum* sp. mainly infected *O. leucostictus* from the Main Lake except for one single specimen of *O. leucostictus* from Olodien Bay which had five parasites encysted in the buccal cavity (tables 2 and 3).

A significant difference was observed in the abundance of parasites within sampling stations ($P < 0.001$), e.g. *Contracaecum* sp. was more abundant in *O. leucostictus* from Oloidien Bay (maximum intensity of infection = 78) than those from the Main Lake (maximum intensity = 35). *Polyacanthorhynchus kenyensis* was more abundant in fish species from the Main Lake (maximum intensity = 104) compared with those in Oloidien Bay (maximum intensity = 59) (tables 2 and 3).

An equally significant difference was observed between the prevalence of *Contracaecum* sp. and *P. kenyensis* and host size of the two fish species ($P > 0.001$) (fig. 2). Also, male fish were more heavily infected than females ($P < 0.05$) (table 4). Despite harbouring heavy infections of both *P. kenyensis* and *Contracaecum* sp., the body condition of *O. leucostictus* remained unaffected ($P > 0.05$) (fig. 3). However, it was noted that both fish species from Oloidien Bay matured at much smaller sizes and without fat deposits around the digestive caecum, compared with the Main Lake where both fish hosts were larger in size and contained abundant fat deposits.

Discussion

The absence of ectoparasites on *O. leucostictus* and *T. zillii* which were introduced from Lake Victoria was unique to Lake Naivasha as ectoparasites have been recorded on the same fish species from other tropical water bodies (Paperna, 1980; Douellou, 1992). *Tilapia* species from Lake Victoria have been reported to harbour ectoparasites such as *Argulus* sp. and *Dolops* sp. which are also common among cichlid fish (Fryer & Iles, 1972). Ectoparasites are sensitive to changes in environmental conditions hence those parasites which might have been present on fish from Lake Victoria could have disappeared due to changes in the water chemistry (Dubinin, 1958). The low intensity of infection with most of the parasites in *T. zillii* concur with results of Roberts & Sommeville (1982) that among the tilapiine species, *T. zillii* is more resistant to parasitic infections than the other fish species.

In the present study, *Contracaecum* sp. was the only parasite found free floating in the pericardial cavity of

Table 2. The intensity of infection of helminths in *Oreochromis leucostictus* relative to sampling sites.

Sampling site	Number of fish examined	Helminth species (mean worm numbers ± SE)			
		Contracaecum sp.	*Polyacanthorhynchus kenyensis*	*Clinostomum* sp.	*Cyclustera* sp.
North swamp	92	1.68 ± 0.18	6.46 ± 1.66	0.78 ± 0.21	3.9 ± 0.97
Crescent	132	0.5 ± 0.13	4.77 ± 1.36	0.35 ± 0.16	2.15 ± 1.2
Safariland	117	0.77 ± 0.19	1.58 ± 0.38	1.21 ± 0.35	1.09 ± 0.6
Oseria	123	0.78 ± 0.19	1.52 ± 0.36	0.55 ± 0.2	0.5 ± 0.14
Hippopoint	84	0.85 ± 0.18	4.42 ± 1.92	0.45 ± 0.15	1.72 ± 0.5
Oloidien	101	15.13 ± 2.33	2.58 ± 0.80	0.27 ± 0.13	1.32 ± 0.35

Table 3. The intensity of infection of helminths in *Tilapia zillii* relative to sampling sites.

Sampling site	Number fish examined	Helminth species (mean worm numbers ± SE)			
		Contracaecum sp.	*Polyacanthorhynchus kenyensis*	*Clinostomum* sp.	*Cyclustera* sp.
North swamp	87	0	1.64 ± 0.57	1.2 ± 0.38	0
Crescent	112	0	1.62 ± 0.57	1.2 ± 0.3	0
Safariland	63	0	2.0 ± 0.50	1.1 ± 0.6	0
Oseria	101	0	1.67 ± 0.81	1.1 ± 0.29	0
Hippopoint	53	0	2.75 ± 0.92	0.7 ± 0.3	0
Oloidien	32	1.42 ± 0.38	1.15 ± 0.14	1.5 ± 0.5	0.68 ± 0.21

O. leucostictus. These findings suggest that fish become infected through a direct pathway rather than through a first intermediate host (Malvestuto & Ogambo-Ongoma, 1978). In general, temperate freshwater fish acquire larval *Contracaecum* sp. via a first intermediate host, usually a zooplankton, and Huizinga (1966) concluded that direct infection of fish by this parasite is not the usual pathway followed in nature. However, Fryer & Iles (1972) indicated that many tilapiine species in East Africa feed primarily on phytoplankton and decomposed organic matter so it is possible that *O. leucostictus* from Lake Naivasha are directly infected by *Contracaecum* sp. during feeding and without the intervention of an intermediate host. This, in any case, is likely to be the primary method of infection in any aquatic environment where phytoplanktivorous fish are present (Malvestuto & Ogambo-Ongoma, 1978).

According to Ogambo-Ongoma (1975), the second stage larvae of *Contracaecum* sp. may be ingested directly by the fish host or be eaten by a copepod and the fish in turn becomes infected by eating the copepod. Therefore, *T. zillii* appear to become infected through feeding on infected copepods as Muchiri (1990) reported that copepods form part of their diet in Lake Naivasha. Paperna (1980) also observed that third stage larvae of nematodes may occur freely or encysted in the host tissue depending on its feeding habits. The development of *Contracaecum* sp. in temperate water bodies has been reported by Hunzinga (1966). Fish species act as intermediate hosts to third stage larvae of the parasite. Eggs are deposited in the water with bird faeces and develop into first stage larvae, which moult and become second stage larvae which are either ingested by the fish directly or through an infected copepod. The parasite attains maturity in piscivorous birds such as cormorants and pelicans. In the present study, up to about 300 mature worms were recovered in one pelican which was accidentally trapped in the gill nets.

Polyacanthorhynchus kenyensis was observed to encyst inside the liver of their hosts which contradicts other reports that acanthocephalans are mainly parasites of the intestine (Paperna, 1980; Amin, 1985; Køie, 1988).

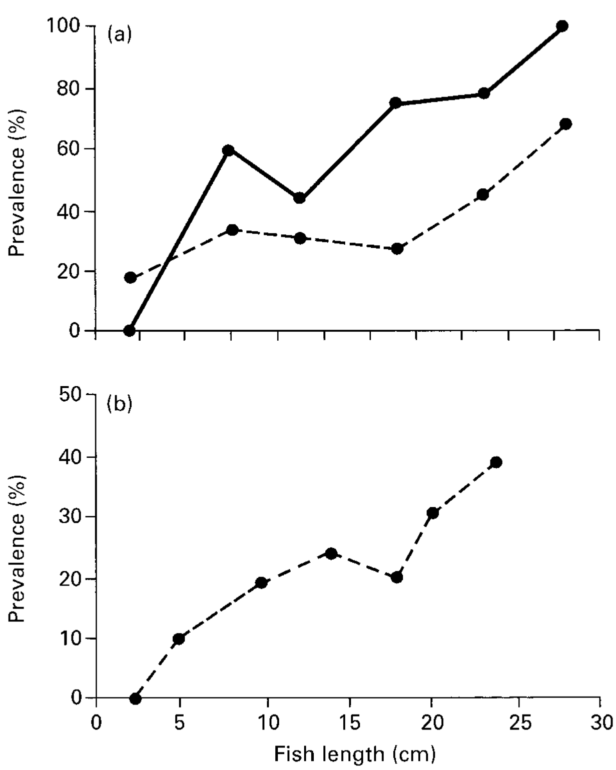

Fig. 2. The prevalence of *Contracaecum* sp. (—) and *Polyacanthorhynchus kenyensis* (- - -) in *Oreochromis leucostictus* (a), and *P. kenyensis* in *Tilapia zillii* (b), relative to host size (body length).

Table 4. The prevalence and intensity of infection of (a) *Oreochromis leucostictus* and (b) *Tilapia zillii* with helminths relative to host sex.

(a)	Helminth	
Sex	*Polyacanthorhynchus kenyensis*	*Contracaecum* sp.
Males	46.4 (72)	68.2 (69)
Females	20.6 (55)	31.5 (51)
(b)	Helminth	
Sex	*Polyacanthorhynchus kenyensis*	*Contracaecum* sp.
Males	19.2 (57)	2.4 (38)
Females	8.6 (63)	1.8 (11)

$F_{1,3} = 27.87$; $P < 0.05$.
Numbers in parentheses indicate prevalence.

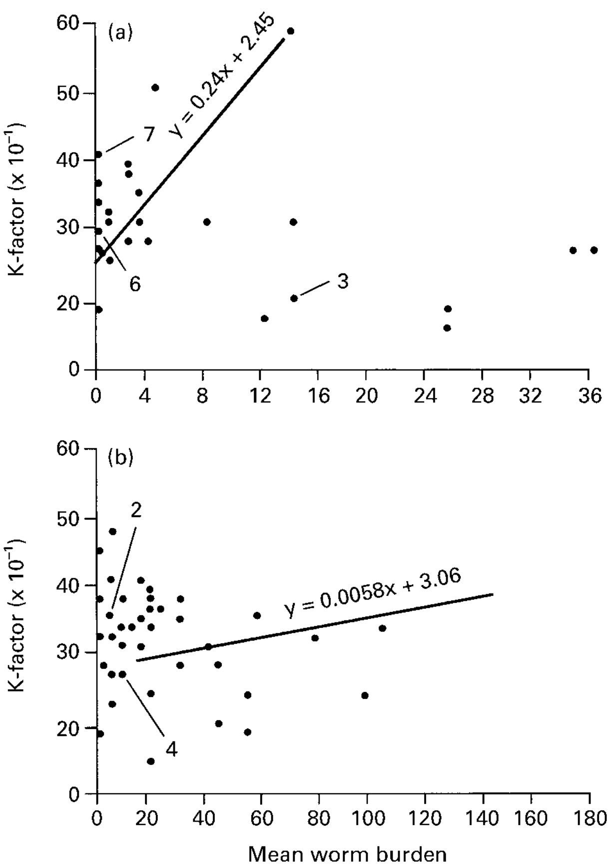

Fig. 3. The effects of worm burdens of (a) *Contracaecum* sp. and (b) *Polyacanthorhychus kenyensis* on the health status, defined as condition factor (k), of *Oreochromis leucostictus*. Number of fish sampled = 50.

Acanthocephalans require vertebrates as definitive hosts and arthropods, i.e. isopods, amphipods, copepods and ostracods as intermediate hosts. A list of known acanthocephalan intermediate hosts was reported by Schmidt (1985). Isopods and amphipods are absent from Lake Naivasha (Aloo, 1995) and none of over 100 ostracods dissected by Aloo & Dezfuli (1997) had any acanthocephalans. In South Africa Amin (1987) reported mature acanthocephalans in caimans (Alligatoridae) while Schmidt & Canaris (1967) reported that adult species of the parasite occur in crocodiles. As infected crustaceans were not found and the fact that both alligators and crocodiles are absent from Lake Naivasha, the life cycle of *P. kenyensis* in Lake Naivasha is still unknown. However, since only immature species of *P. kenyensis* were recovered from the two fish species, it is possible that the two tilapias act as paratenic hosts.

The occurrence of *Amirthalingamia* sp. and *Cyclustera* sp. encysted in the intestine and liver of fish agree with the findings of Okedi (1980) and Scholz & Capellaro (1993) that cestodes are common parasites of the intestine and liver where they usually encyst. Cestodes have been reported to use fish as second intermediate hosts where the fish acquire infection through feeding on infected crustaceans such as *Diaptomus* or *Cyclops*. Adult cestodes live in the intestine of humans and other fish-eating mammals (Scholz, 1986). The life cycle of both cestode species in Lake Naivasha remains unknown.

Although the digenetic trematode, *Clinostomum* sp. is mainly found in the alimentary tract of its host, the present study found this digenean encysted below the operculum and pharyngeal region. Digeneans in aquatic environments use snails especially *Lymnaea natalensis* as first intermediate hosts with fish acting as the second intermediate host and aquatic birds such as ducks as the definitive host. A preliminary attempt to expose 20 *L. natalensis* to strong light revealed the release of one cercaria of *Clinostomum* sp. so further studies are needed to establish the life cycle of this digenean in Lake Naivasha.

The lack of seasonality in parasite prevalence in both *O. leucostictus* and *T. zillii* suggest that the fish are infected throughout the year. These results agree with those of Scholz (1986) on *Acanthocephalus lucii* which occur in *Perca fluviatilis* throughout the year. However, Paperna (1980), Mbahinzireki (1984) and Batra (1984) reported seasonal variation of various parasite species in tropical waters. In temperate regions, Amin (1985) and Scholtz (1986) reported the seasonal occurrence of acanthocephalan species while Crozier (1987) demonstrated the seasonality of *Contracaecum* sp. in angler fish. In tropical climates, seasons are not clearly defined therefore parasite life cycles tend to be more continuous through their intermediate hosts (William & Jones, 1994). This perhaps explains the situation in Lake Naivasha.

There are various reports on the prevalence and intensity of parasites infecting freshwater fish species in Africa (Paperna, 1980). In Lake Naivasha, Malvestuto & Ogambo-Ongoma (1978) reported that 85% of 2572 *Tilapia leucosticta* examined were infected with third stage larvae of *Contracaecum* sp. with nine worms per fish. However, the present study has established that 58% of *Oreochromis leucostictus* from the Main Lake were infected with a mean of two worms per fish, while 98% of fish species from the Oloidien Bay were infected with *Contracaecum* sp. with a mean intensity of 15 worms per fish. Ogambo-Ongoma (1975) reported a prevalence of 30% of *Tilapia grahami* with *Contracaecum* sp. from Lakes Nakuru and Magadi with two worms per fish, while Paperna (1974) reported 30% of *T. nilotica* from Lake George to be infected with one worm per fish. Mashego (1989) reported a prevalence of 50% and a mean intensity of 30 *Contracaecum* sp. in *Barbus mattozi* from South Africa. There are no previous reports on the infection of *T. zillii* which can be compared with the present findings. However, it is worth noting that only 1.2% of *T. zillii* from Oloidien were infected with this nematode species.

With regard to the acanthocephalan, *P. kenyensis*, Schmidt & Canaris (1967) reported prevalences ranging from 30.4% to 86.9% in *O. leucostictus* and 4.1% to 77.7% in *T. zillii* while in non-cichlid fishes, ranges of 20% to 50% in *Micropterus salmoides* and 5.8% to 100% in *Barbus amphigrama* were observed. In the present study, 90% of *O. leucostictus* from the Main Lake were infected with *P. kenyensis* with a mean intensity of 11 worms per fish. However, fish from Oloidien Bay had a prevalence of 35% with a mean intensity of two worms per fish. *Tilapia zillii* from the Main Lake had a prevalence of 30% with a mean intensity of one worm per fish while those from Oloidien Bay had a prevalence of 14% with a mean intensity of five worms per fish. Although *T. zillii* from Oloidien Bay showed a low prevalence, the fish had a higher worm burden than those from the Main Lake where the prevalence was much higher but mean worm burdens were low. The remainder of the helminth fauna of the two tilapiine species occurred in low numbers and no significant comparisons can be made.

The fact that fish from the saline Oloidien Bay were more heavily infected, especially with the nematode *Contracaecum* sp., agrees with Dogiel *et al.* (1958) that parasites not always requiring intermediate hosts such as *Contracaecum* sp. are likely to occur abundantly in saline environments. The remaining parasites, i.e. *P. kenyensis*, *Clinostomum* sp., *Amirthalingamia* sp. and *Cyclustera* sp. all occurred in low numbers in Oloidien Bay as the intermediate hosts are unlikely to withstand high salinities. Moreover, under saline conditions such as in Oloidien Bay, fish hosts are stressed and are more susceptible to parasitic infections and this is clearly demosnstrated by *O. leucostictus* from Oloidien Bay where fish are more heavily infected than those from the Main Lake. Differences in the intensities of infection of the two tilapiine species in Oloidien Bay and the Main Lake could also be attributed to their different feeding habits. Fish from Oloidien Bay, especially *O. leucostictus*, feed mainly on benthic materials including detritus, thereby picking up larval stages of parasites compared with tilapias from the Main Lake which feed mainly on insect larvae (Muchiri, 1990).

The prevalences of *Contracaecum* sp. and *P. kenyensis* in the two fish species increased in the larger sized fish because the latter consume more food containing larval stages of the parasites. Also, the older or larger sized fish experience longer exposures to the parasites hence there is accummulation of parasites over the years. Similar findings have been reported by Paperna (1980) on tilapias, Valtonen (l983) on *Coregonus laveratus*, Crozier (1987) on *Lophius piscatorius*, Mashego (1989) on *Barbus mattozi*, Erlwanger (1991) on *Tilapia rendalli* and Patrick *et al.* (1992) on *Rhinichthyes cataracta*.

Oreochromis leucostictus and *T. zillii* from Lake Naivasha conform to the more typical situation where the degree of infection in male fish is higher than that in females. These observations agree with those of Thomas (1964) on Lake Windermere trout, Paling (1965) on brown trout and Batra (1984) on cichlids. They attributed these findings to physiological, i.e. endocrine changes in the female fish.

Despite visible lesions caused by the acanthocephalan *P. kenyensis* on the liver of fish, the parasites species did not appear to have any effect on the condition factor of heavily infected *O. leucostictus*. Acanthocephalans have not been observed to be serious pathogens of fish, although the insertion of the spiny proboscis in the liver does lead to the destruction and necrosis of tissues (Paperna, 1980). Although specimens of *Contracaecum* sp. possessed red coloration, an occurrence suggesting they feed on blood, this did not appear to have any effect on the overall condition factor of the fish host. Reports on nematodes from other tropical waters have indicated that they are usually harmless to their hosts (Tompkins, 1976; Mbahinzireki, 1984), although Paperna (1980) pointed out that nematodes may not be too harmful to their fish hosts but the marketability of the fish is greatly reduced.

In general, Chubb (1965) reported that in the natural environment, parasites are always in a complex equilibrium with their hosts, normally posing no harmful effects to their hosts. This equilibrium is maintained as long as the environment is not disturbed and provided the hosts, in this case fish, are not subjected to any stressful conditions. Lake Naivasha is surrounded by large commercial farms where large quantities of pesticides are used and these chemicals may accumulate in the lake leading to stressful conditions that might make fish more susceptible to parasitic infections in the future. Finally, the disparity in the sizes of the two tilapiine species from the two water bodies under investigation can be attributed to the fact that the Oloidien Bay is more saline which may in turn affect the growth and development of the two tilapiine species (Muchiri, 1990; Aloo, 1995).

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