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Hydatid disease in the Turkana District of Kenya, IV

The prevalence of *Echinococcus granulosus* infections in dogs, and observations on the role of the dog in the lifestyle of the Turkana

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The prevalence of *Echinococcus granulosus* in dogs in the Turkana district of Kenya was 39·4% of 695 examined. Of these, 98 (35·8%) had heavy *Echinococcus* worm burdens (10^3–5×10^4), while 54 (19·7%) and 122 (44·5%) had medium (201–1000) and light (1–200) burdens. The possible sources of these infections are discussed.

The prevalence rate differed in various parts of the district, ranging from 63·5% in the north-west, where the highest incidence of human hydatidosis also occurs, to nil along the shores of Lake Turkana. Infection rates of 32·0% and 16·7% were recorded at Lokitaung (north–east) and Lodwar (central), while in the south 48·9% of dogs harboured *Echinococcus*. This latter figure is surprising as the area has a low incidence of human hydatidosis.

The Turkana keep a large number of dogs, and the reasons for this and the social role of the dog in the district is discussed.

No difference in susceptibility was found between Turkana-type dogs and those of mixed breeds from Nairobi when they were experimentally infected with hydatid protoscolices from man, camels, cattle, sheep and goats. However, it proved difficult to infect the Turkana-type of dogs with viable protoscolices of cattle origin. The reasons for this and its epidemiological implications remain unclear.

It is suggested that droughts, which affect Turkana every six to ten years, may play an important role in the perpetuation of hydatid disease in the area.

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The highest known incidence of human hydatid disease is found in the north of Turkana District, in north–western Kenya. The various hypotheses which have been formulated to account for this and the geographical distribution of this disease, throughout the district, have been presented in the first two papers of this series (French and Nelson, 1982; French *et al.*, 1982).

The Turkana keep dogs for several different reasons according to their individual requirements. Some children are allowed to keep dogs as playthings. Their mothers train a dog to act as a nurse to each infant. These dogs lick the infant clean when it is soiled as a result of defaecating or vomiting, and they also remove any excreta which has been deposited within the dwelling. These dogs also provide protection against attack by wild animals, such as jackals, during the prolonged periods that the mother leaves her infant to fetch water, the only source of which may be up to 5 km away. Women require a dog for cleansing during the menses. Men do not have such special needs for keeping dogs, although some maintain a guard dog to protect their livestock (French and Macpherson, in press).

There is also a large feral dog population which scavenge from the settlements (manyattas). Such dogs are tolerated by the Turkana, who make no effort to control their number. Occasionally one might be destroyed if it has killed a young animal or stolen food. There also exist a few truly feral dogs, but these do not frequent areas of human habitation.

The geographical isolation of the Turkana district has, until very recently, allowed the peoples' traditional customs to remain largely unaffected by outside influences. There have also been no governmental dog control programmes, as rabies has not yet been detected. The overall dog population in Turkana is approximately 50 000 individuals, but the density varies throughout the district (French and Macpherson, in press).

Turkana dogs are small in stature, standing about 50 cm at the shoulder; they have pointed ears and the tail is held coiled over the back. They are short haired and usually either brown or black with white underparts and white areas on the legs and face. This type of dog is found throughout the district, but those living near the lake are larger, presumably because they have access to more food from the fishermen's practice of discarding fish offal. In other parts of Turkana dogs receive only scraps of unwanted food. During mass slaughter any infected offal, including hyatid cysts, is thrown to the dogs.

The only previous investigation of *Echinococcus* infections in dogs in Turkana was that made by Nelson and Rausch (1963) at Lokitaung (see Fig. 1). An attempt was made to reassess the prevalence and the intensity of infection in dogs and to extent the study to include the whole of Turkana district. It was hoped that it would thus be possible to assess the infection pressure to man and his domestic livestock and to find out if this correlated with the known distribution of the disease in man.

It was only in Turkana dogs that Nelson and Rausch (1963) found "intestines 'furred' with thousands of worms" and since these dogs form a distinct group, it seemed possible that they could be especially susceptible to infection with *E. granulosus vis à vis* other dogs in Kenya. Experimental infections were therefore undertaken to investigate this possibility.

Also, since the infectivity of hydatid material from man, camels, cattle, sheep and goats to dogs in Kenya was unknown, the susceptibility of dogs to experimental infection with material from these five hosts was studied.

MATERIALS AND METHODS

Natural Infections

During the period April 1979 to February 1983, surveys were carried out to examine the prevalence of *E. granulosus* infections in domestic dogs throughout Turkana (Fig. 1). Efforts

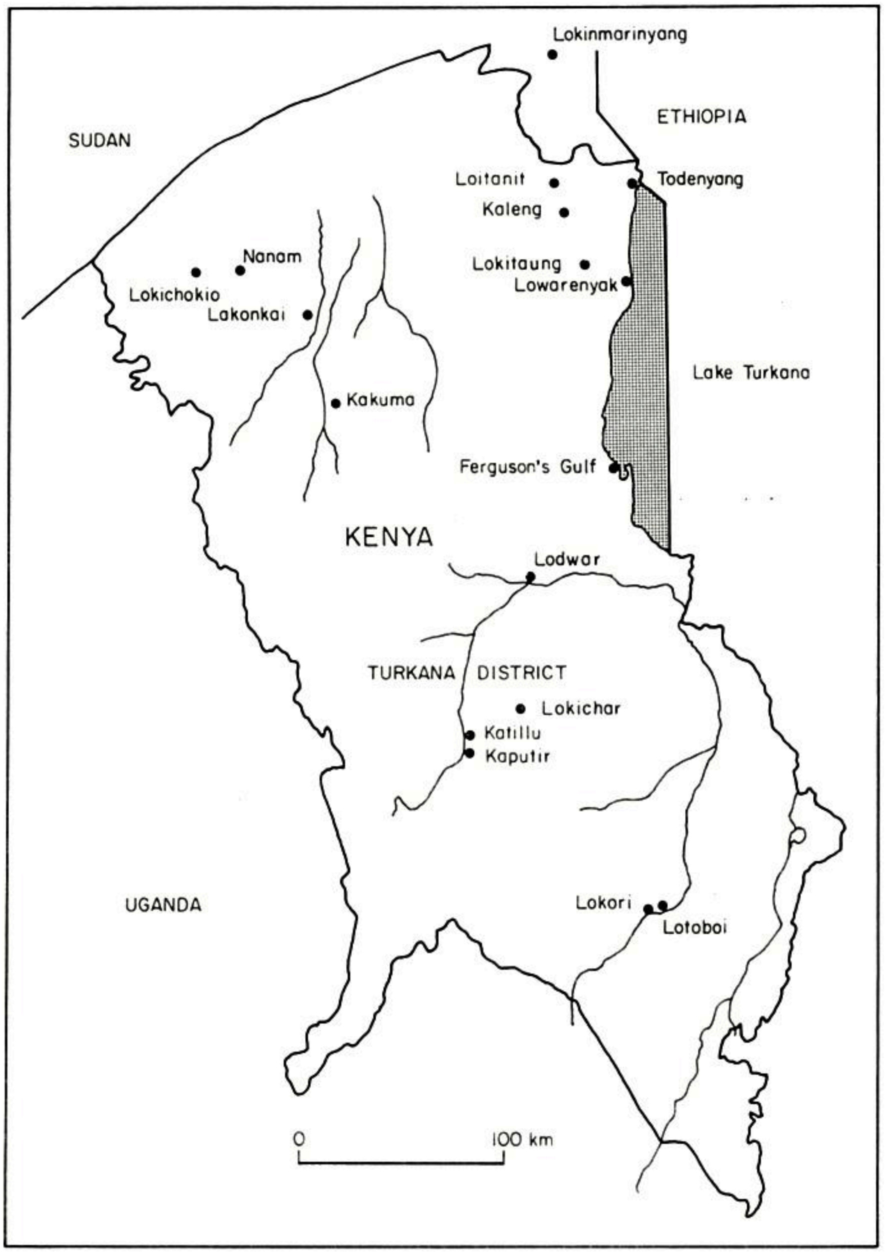

Fig. 1. Map of Turkana District showing places where dogs were examined for the presence of *Echinococcus granulosus*.

were made to ensure that the different lifestyles and various geographical and environmental features found in Turkana were included, as were areas where extremely high and low incidences of human hydatidosis had been reported.

Feral dogs were destroyed by shooting and domestic dogs were either shot or, more usually, were brought to us for euthanasia with intracardiac or intravenous injections of

Euthatal (pentobarbitone sodium, May & Baker Ltd., Dagenham, UK). Occasionally dogs were kept near the camp and starved for 24 hours before being killed. This provided the advantage of examining empty intestines so that the small *E. granulosus* adult worms were much easier to detect and to remove cleanly. For each dog provided, the Turkana received a nominal payment of 5–20 Kenya shillings (25–100 p UK) plus a small gift of chewing tobacco.

Immediately after death, the small intestines of the dogs were removed *in toto* and, after rinsing in normal saline to remove any external blood, the intestines were opened under fresh saline in large black-bottomed trays.

If no *E. granulosus* were seen, the intestinal mucosa was scraped and examined by washing and decanting with fresh saline. Some intestines were examined by eye only. Any worms found were relaxed for 30 minutes in saline and were counted, unless obviously exceeding 1000 individuals; they were then fixed in 70% ethanol or in 10% formal saline. Care was taken to secure container tops as formalin does not kill *Echinococcus* eggs (Hercus *et al.*, 1962).

Objects which appeared on gross examination to be either whole worms or segments of *E. granulosus* were kept for microscopic examination later. In all cases where adult worms were visible, their position along the intestine was measured from the pylorus.

Other parasites present in the small intestine were processed in the same way as the *E. granulosus* specimens. Many of these were later identified microscopically and the *Taenia* spp. were identified using the classifications of Verster (1969).

Experimental Infections

A total of 46 puppies, all from litters of at least three individuals, were purchased from Turkana tribesmen and from people living in Nairobi. The puppies, all less than 16 weeks old, were dosed with Canex® (pyrantel pamoate, Pfizer Agricare Pty. Ltd., UK) to remove roundworm and hookworm infections. Additionally, prior to experimental infection, most puppies received 10 mg kg^{-1} bodyweight of Droncit® (praziquantel, Bayer, Leverkusen, Germany) to eliminate any possible naturally acquired *E. granulosus* infections.

The animals were starved for 21 hours before being fed a gelatin capsule containing approximately 160 000 packed protoscolices, obtained from a hydatid cyst from one of the intermediate hosts (man, camel, cattle, sheep or goat). Immediately before administration, protoscolices were checked for viability and only used if viability exceeded 60%. Puppies from the same litter were infected with the same source of hydatid material. The number of puppies infected with each source of protoscolices is shown in Table 3.

Puppies were examined at autopsy between 34 and 38 days later, i.e. before the adult worms became ovigerous. Three puppies fed protoscolices from a human patient were examined 40 days post-infection.

Puppies were starved for 18 hours prior to autopsy and killed with an intravenous injection of Euthatal. The small intestines were removed, opened longitudinally, divided into 30 cm lengths from the pylorus and incubated in separate beakers of prewarmed (37°C) Hank's Balanced Salt Solution (HBSS) for one and a half hours.

After this time the intestines were scraped, and the numbers of worms estimated by suspending all the worms from each section in 100 ml aliquots. Worms were counted individually in light infections.

RESULTS

Natural Dog Infections

Of the 695 dogs examined throughout Turkana district, 274 (39·4%) were found to harbour *E. granulosus* infections. The prevalence and intensity of the infections was variable (Table 1).

TABLE 1

Regional differences in the prevalence and intensity of Echinococcus granulosus *infections in 695 dogs examined throug[h] Turkana from April 1979 to February 1983*

Location in Turkana	*Place*	*Date*	*Sex of dogs*	*Number examined*	*Number infected*	*Percentage infected*	Intensity of Echinococcus *infection*: *Light (1 200 worms)*	*Medium (201 1000 worms)*	*Hea[vy] (> 1[000] worm[s])*
North west	Kakuma	April 1979	M	13	7	53·8	6	0	1
			F	16	10	62·5	9	0	1
	Lakonkai	April 1979	M	13	9	69·2	4	0	5
			F	21	13	61·9	9	1	3
	Lokichokio I	June &	M	28	15	53·6	8	1	6
		December 1979	F	33	20	60·6	9	8	3
	Lokichokio II	June 1980, 1981	M	37	26	70·3	11	5	10
		& December 1982	F	50	32	64·0	8	4	20
	Nanam I	June 1980	M	17	11	64·7	3	3	5
			F	20	16	80·0	3	5	8
	Nanam II	August 1982	M	8	5	62·5	1	2	2
			F	7	3	42·9	1	2	0
	Total			263	167	63·5	72	31	64
North east	Lokitaung I & Loitanit & Kaleng	August 1979	M	17	5	29·4	2	1	2
			F	19	1	5·3	1	0	0
	Lokitaung II & Kaleng	March 1981	M	23	9	39·1	6	3	0
			F	16	9	56·3	6	2	1
	Todenyang & Lowarengak	March 1982	M	6	3	50·0	3	0	0
			F	7	0	0·0	0	0	0
	Lokinmarinyang	May 1982	M	2	2	100·0	2	0	0
			F	1	0	0·0	0	0	0
	Total			91	29	31·9	20	6	3
Central	Ferguson's Gulf Area	November 1981 & March 1982	M	40	0	0·0	0	0	0
			F	40	0	0·0	0	0	0
	Kalakol Town	November 1981	M	13	2	15·4	0	1	1
		March & Aug. 1982	F	12	4	33·3	2	2	0
	Lodwar & environs	November 1981	M	64	6	9·4	4	0	2
		& March 1982	F	62	15	24·2	9	4	2
	Lorugumu	November 1981	M	8	4	50·0	1	2	1
			F	8	1	12·5	1	0	0
	Total			247	32	13·0	17	9	6
South	Lokori/Lotoboi I	September 1979	M	7	2	28·6	0	0	2
		& July 1980	F	8	6	75·0	2	1	3
	Lokori/Lotoboi II	March 1982 &	M	14	7	50·0	2	1	4
		February 1983	F	37	18	48·6	3	2	13
	Lokichar	March 1982	M	2	1	50·0	1	0	0
			F	10	3	30·0	1	0	2
	Katillu	March 1982	M	5	2	40·0	0	2	0
			F	6	2	33·3	2	0	0
	Kaputir	April 1982	M	2	2	100·0	2	0	0
			F	3	3	100·0	0	2	1
	Total			94	46	48·9	13	8	25
			M (total)	319	118	38·3	54	21	41
			F (total)	376	156	41·5	66	33	57
	Total all areas	April 1979 February 1983		695	274	39·4	122	54	98

Fig. 2. Turkana dog small intestine completely carpeted with adult *Echinococcus granulosus*. Heavy infections such as this were found in 98 (35·8%) out of 274 infected dogs seen in this district.

Fig. 3. Hundreds of adult *Echinococcus granulosus* worms, removed from the small intestine of a dog, lying on the bottom of a dissecting dish. The bottle top gives an indication of their small size.

TABLE 2

Distribution of Echinococcus granulosus *adult worms along the small intestine (measured from the pylorus) of dogs examined in Turkana*

E. granulosus *infection*	*Distribution along the intestine (cm) from the pylorus* — *Infection begins*	*Infection ends*	*Mean distribution*
Light (200 worms)	29	94	48–68
Medium (201–1000 worms)	5	158	46–99
Heavy (1001 worms)	2	300	35–135

TABLE 3

Experimental infections of Echinococcus granulosus *produced in dogs by feeding them protoscolices obtained from hydatid cysts removed from domestic animals and man*

Source of larvae	*Origin of dog infected*	*No. of dogs exposed to infection (and no. infected)*	*Percentage of worm population along gut (cm) from pylorus*				*Average no. of worms recovered per infected dog*
			0–30	*31–60*	*61–90*	*91–End*	
Human	Nairobi	12 (8)	44·6	54·3	1·1		10 233
(Turkana	Turkana	8 (7)	16·0	57·2	26·0	0·8	8 081
and Masai)	Total	20 (15)	26·3	56·0	17·3	0·4	9 311
Camel	Nairobi	3 (3)	12·5	45·6	33·2	8·7	10 565
(Turkana)	Turkana	1 (1)	13·0	48·0	31·8	7·2	12 100
	Total	4 (4)	12·8	46·8	32·5	7·9	11 332
Cattle	Nairobi	4 (3)	28·0	30·0	41·6	0·3	7 087
(Masai and	Turkana	9 (1)	68·0	32·0			200
Turkana)	Total	13 (4)	48·0	31·0	20·8	0·2	5 385
Sheep	Nairobi	2 (2)	24·7	46·3	29·0		11 868
(Masai)	Turkana	3 (3)	46·7	45·0	7·3	1·0	8 180
	Total	5 (5)	30·3	46·0	23·4	0·3	10 024
Goat	Nairobi	0 (0)					
(Turkana)	Turkana	4 (4)	49·3	27·6	22·4	0·7	10 221
	Total	4 (4)	49·3	27·6	22·4	0·7	10 221

The distribution of adult *E. granulosus* along the intestine varied from dog to dog, but the worms were usually located between 37 and 125 cm from the pylorus. In heavy infections worms would completely 'carpet' almost the entire length of the small intestine (Figs. 2 and 3), beginning 2·0 cm from the pylorus and extending up to 300 cm from it (Table 2). From sedimented volumes, it was calculated that approximately $4–5 \times 10^4$ individuals were present in such infections.

The sex of the dog did not appear to affect the prevalence or intensity of *E. granulosus* infections found. Unfortunately it proved impossible to determine the ages of any of the dogs examined.

Other intestinal parasites found in the dogs included *Ancylostoma caninum*, present in 23 dogs. The maximum number of hookworms in any infection never exceeded five individuals. A few dogs harboured ascarids. Most dogs examined contained *Taenia* spp., almost all of which were *Taenia hydatigena*. The mean number of *T. hydatigena* recovered from 415 infected dogs was 5·3, and burdens ranged from one to 98 worms. A single *T. multiceps* specimen was positively identified and a few dogs harboured *Dipylidium caninum* and *Spirometra* sp.

Experimental Infections

The results obtained from the experimental infections are shown in Table 3.

Thirty-one of the 46 puppies fed viable protoscolices from various hosts were found to harbour numerous *E. granulosus* worms *post mortem*. Five out of 20 puppies fed human protoscolices and nine out of 13 fed cattle protoscolices were negative for *E. granulosus*.

In the infected puppies, most of the worms were found in the first 90 cm of the small intestine. On average 7×10^{3}–1×10^{4} worms were recovered from each infected puppy, but this varied considerably between animals.

DISCUSSION

The high prevalence and heavy *E. granulosus* infections, coupled with the large dog population and the close human/dog relationships in Turkana, provide ideal conditions for the successful transmission of the parasite to man. Indeed, in areas in north-western Turkana where the highest incidence (198 per 100 000 per year; French and Nelson, 1982) of human hydatidosis is found, the highest man/dog ratio (1 : 0·36; French and Macpherson, in press) and the highest *E. granulosus* prevalence in dogs were also found.

Much lower prevalences of *E. granulosus* were found in dogs examined in north-eastern Turkana (31·9%) and in and around Lodwar (16·7%). The reasons for this are unclear, but they may be related to better meat inspection in the towns and because dogs have less access to infected offal. The lower prevalence found in these areas suggests a lower infection pressure for man and indeed the incidence of human hydatidosis in the two areas is comparatively lower.

The prevalence of *E. granulosus* infections in dogs in southern Turkana was only slightly lower than that found in the north-west, and heavier worm burdens were found in the south. This does not correlate with the human incidence of hydatidosis, which is ten times lower in the south than the north-west (French and Nelson, 1982). This could be related to the man/dog ratio which is much lower in the south (1 : 0·12). Hence, even though the same proportion of dogs are infected, the total infection pressure for humans would be lower. This area is populated by the Ngisonyoka, a clan of the Turkana, who because of the presence of surface water (in the Kerio River) for much of the year, do not make as much use of the dogs for cleansing procedures. The Ngisonyoka therefore tend to have less frequent and less close contact with dogs than the clans in the north. Additionally some of the people in southern Turkana refuse to allow dogs into the huts at night, leaving them to sleep in special areas outside the hut. This would greatly reduce the amount of man/dog contact in this area of Turkana.

One wonders what would have been the conclusions of any former researchers in Turkana had they only examined dogs for *Echinococcus* in the Ferguson's Gulf area? Of the 80 dogs we examined, none were found to harbour the adult parasite and yet hydatid disease is reported in the people living there. This may be due to the fact that most of these people were moved from other parts of Turkana (particularly from Lokichokio/Kakuma), because of the severe famine of the early 1960s when fishing was introduced to provide a source of food. These people now tend to move from the lake shore for short journeys to the interior, invariably leaving their livestock and dogs behind. It seems likely that the cases of hydatidosis seen in this location were, and probably still are, contracted in their original home areas. The reasons why the dogs are uninfected in this area is probably related to their diet. Kalakol is the centre of the fishing industry and from examination of the stomach contents, it was found that the dogs fed almost exclusively on fish.

Although the prevalence of *E. granulosus* infection in dogs is high throughout the district, the exact source of these infections remains uncertain. For, surprisingly, hydatid disease in the domestic livestock is very low, being less than 2·0% in cattle, sheep and goats, but up to 80% in camels (Macpherson, 1981).

By examination of the glucosephosphate isomerase (GPI) and phosphoglucomutase (PGM) isoenzyme patterns of worms from some of the naturally infected dogs from Lokichokio, it was found that most of the infected dogs harboured *Echinococcus* adults exhibiting the human/sheep/goat pattern (Macpherson and McManus, 1982). Whilst this result is not conclusive, it does support our limited epidemiological evidence. Although camels have a high prevalence of the disease, their relative importance in the maintenance of the parasite may be limited, as very few are ever slaughtered. Similarly, cattle probably play a minor role because not only are few slaughtered, but they also have a low prevalence and any cysts are usually sterile. On the other hand, sheep and in particular goats have a low prevalence, but they are slaughtered in far greater numbers and may therefore be of greater significance in the transmission of the parasite. According to local custom, few people are buried, therefore man, who appears to be an excellent intermediate host for the parasite, also plays an active role in the perpetuation of the parasite's life cycle in Turkana and especially those areas of high human incidence (Nelson, 1972; Mann, 1974; Macpherson, 1983). No wild animals infected with hydatids have been found in Turkana and the wildlife is therefore unlikely to be a source of the dog infestations (Macpherson, Karstad, Stevenson and Arundel, 1983).

With the low prevalence of hydatid cysts in cattle, sheep and goats and the fact that few camels are slaughtered, the high prevalence found in the dogs is perplexing. One explanation could be the longevity of the adult parasite which have been recorded to remain patent for up to two years (Sweatman and Williams, 1963). Thus, even if only rare infection opportunities exist, and because of the worms' longevity, this means that over a period of time, in the absence of treatment, a large proportion of dogs could become infected. Another factor could be the effect of droughts, which plague Turkana every six to ten years. During the present study, the prevalence of *E. granulosus* infections in dogs at Lokichokio rose after the drought (June and December, 1979) from 57·4% to 66·7%. During this time an estimated 70–90% of the domestic livestock died, and the proportion of heavily infected dogs rose from 25·7% to 51·7%. Since the methods for collecting and examining the dogs were similar throughout, it is likely that there was a real increase in prevalence due to the greater chance of becoming infected. This probably resulted from the increased scavenging opportunities provided by the bodies of people and animals that had died during the drought. It may be, therefore, that droughts causing the death of up to 70% of the domestic livestock play an important part in the survival of the parasite in the inhospitable Turkana environment.

The experimental infections revealed that the dogs appeared to be readily and uniformly susceptible to infections with protoscolices of human, camel, sheep and goat origin, but not to that of cattle material. The reasons why cattle material failed to become established in nine out of 13 dogs remain unclear and requires further study.

The experimental infections also showed that the Turkana dog was no more susceptible to infection with hydatid material than were the dogs purchased in Nairobi. However, infected dogs in Turkana seem to harbour much heavier worm burdens than the dogs from the south of the country. Of 274 infected dogs seen in Turkana, 152 (55·5%) harboured worm burdens of at least 200 worms and many of the heavy infections involved around 5×10^4 individuals. In comparison, Eugster (1978) who found 45 out of 165 (27·3%) dogs in Kajiado to have *E. granulosus* infections, states that '29 dogs revealed more than 20 parasites per individual, thus showing a heavy infection'. To have used such a classification in Turkana would have been of little value, as very few infected dogs harboured less than 20 worms. Nelson and Rausch (1963) also reported that the Turkana dogs had heavier worm burdens than dogs from the Nairobi area.

Heavy *E. granulosus* infections, such as those seen in the Turkana dogs, have also been reported in dogs in southern Sudan (Eisa *et al.*, 1962). Interestingly, the dogs in this region are very similar to the Turkana dog in appearance and behaviour and are probably closely related. Heavy *Echinococcus* worm burdens have also been recorded in naturally infected lions (Dinnik and Sachs, 1968; Eugster, 1978), dingoes (Durie and Riek, 1952; Gemmell, 1959; Coman, 1978) and experimentally infected Cape hunting dogs (Verster, 1965). Such heavy worm burdens could provide the parasite with a very high collective biotic potential, even though individual worms have low biotic potentials in comparison to the other Taenia species.

The need for a control programme in Turkana is paramount, but there are many inherent difficulties in implementing a hydatidosis control programme in this area. Not the least are the nomadic nature of the tribe, the lack of good communications in a difficult environment, the very low literacy rate, the few abattoir facilities and the fact that in this area man himself is an intermediate host for the parasite. In addition, there is the huge dog population with whom the people have a very close contact. Because of these problems, a unique control programme for this area has to be developed. It is our opinion that, like the control programme in Cyprus, any efforts to control hydatid disease in Turkana should be directed against the dogs. It has been evident during our surveys that the Turkana keep many more dogs than they need and they could easily be made to part with them. The wholehearted co-operation received from the Turkana during our surveys suggests that following an educational campaign, a mass dog eradication programme co-ordinated with a mass drug treatment programme of wanted dogs, could be readily implemented in this district.

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