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Hydatid disease in the Turkana District of Kenya

III. The significance of wild animals in the transmission of *Echinococcus granulosus*, with particular reference to Turkana and Masailand in Kenya

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The results are given of a study on the role of wildlife in the transmission of *Echinococcus granulosus* in the Turkana and Narok Districts of Kenya. A total of 76 wild carnivores belonging to three separate species was examined from Turkana District. *Echinococcus* adults were found in 11 of 38 silver-backed jackals (*Canis mesomelas*) and in six of 22 golden jackals (*Canis aureus*). This is the first record of golden jackals being infected with this parasite in Kenya. None of 16 spotted hyaenas (*Crocuta crocuta*) harboured the parasite. Morphological features of the parasites obtained from the jackals were compared with material obtained from dogs in the same area. No morphological differences were recorded when this material was compared with data reported by others, hence the Turkana material belonged to the single species *E. granulosus*. Three silver-backed jackals and three puppies (*Canis familiaris*) were successfully infected with protoscolices obtained from a hydatid cyst surgically removed from a Turkana patient. Three spotted hyaenas fed the same material failed to become infected. None of 152 wild herbivores of five species examined in Turkana harboured hydatid cysts. The natural jackal infections in this District are thought to be incidental and dependent on the continuance of the domestic cycle. The role of the Turkana themselves in the perpetuation of the cycle is discussed. Twenty-six wild herbivores of six species were examined for hydatid cysts, in Narok District; hydatids were found in three wildebeest (*Connochaetes taurinus*) and a single topi (*Damaliscus korrigum*). The discovery of fertile cysts in wildebeest and the reported infections in lions (*Panthera leo*), Cape hunting dogs (*Lycaon pictus*) and silver-backed jackals, support previous evidence of the existence of a wildlife cycle in the Masailand and Serengeti regions of East Africa. The relationship of this cycle to the domestic cycle operating in the same area is unclear and requires further investigation.

Hydatid disease is of considerable medical and public health significance in many countries. The causative agent of unilocular hydatidosis is *Echinococcus granulosus* (Batsch, 1786). The primary maintenance cycle in nature occurs between wild carnivores and wild herbivores, but from the public health point of view the secondary cycle in dogs and domestic animals

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is more important. Other recognized species of *Echinococcus* are maintained in nature in wildlife cycles, e.g. *E. oligarthrus* (Diesing, 1863), which uses wild felids, including the puma, jaguarundi and Geoffrey's cat as definitive hosts and the agouti as an intermediate host; *E. multilocularis*, (Leuckart, 1863) is perpetuated primarily in a cycle involving foxes and microtine rodents; *E. vogeli* (Rausch and Bernstein, 1972) is maintained mainly in a bush dog/paca cycle. The last two species can cause accidental infections in man. Knowledge of the existence of wildlife cycles of some *Echinococcus* spp. is therefore of considerable public health importance; the epidemiological significance of sylvatic *E. granulosus* cycles vary in different regions.

In North America and northern Eurasia the primary maintenance cycles of *E. granulosus* transmission occur between the wolf and the moose, wild reindeer or caribou. These do not readily involve domestic ungulates (Cameron, 1960) and are also independent of man and his livestock (Rausch, 1967). Similar cycles involving jackals and deer may occur in Sri Lanka (Paramananthan and Dissanaike, 1961), and between coyotes and deer in California (Romano *et al.*, 1974). Such cycles are of little public health significance. In Australia, however, sylvatic cycles occur between certain macropods and dingoes which may represent a continuous reservoir of infection for domestic livestock (Coman, 1972). Yet other sylvatic cycles exist whose maintenance appears to depend upon the existence of a domestic cycle, as in the South American red fox and European hare cycle in Argentina (Schantz *et al.*, 1972).

The greatest concentrations of wild large herbivores and carnivores in the world and the greatest assemblages of species are found in East Africa. These are essential parts of the ecosystem, providing ideal conditions for the transmission of *E. granulosus* amongst wild animals. Knowledge of the existence of any wildlife cycles and the possibility of interaction with man and his domestic animals would be important before any control programme was contemplated.

The first definitive host of *E. granulosus* found in Kenya was a jackal (Ginsberg, 1958) and it was hypothesized that jackals and hyaenas might be the main hosts for the parasite in Kenya (Round, 1962). Nelson and Rausch (1963) found heavy infections of *Echinococcus* in 27 out of 43 domestic dogs examined from the Nairobi area and Turkana District. They also examined jackals, hyaenas and a variety of other carnivores and numerous herbivores in Kenya; although they found a few light infections in a silver-backed jackal (*Canis mesomelas*), several spotted hyaenas (*Crocuta crocuta*), and Cape hunting dogs (*Lyacon pictus*), plus hydatid cysts in a single wildebeest (*Connochaetes taurinus*), they concluded that the main cycle of transmission in Kenya is between dogs and domestic livestock. Mango (1971) and Ng'ang'a (1974) supported this theory. However, several authors have reported that numerous species of wild herbivores harbour hydatid cysts in various parts of East Africa. These have been reviewed by Eugster (1978), and are included in a recent bibliography by Karstad (1979). These findings support the idea, that in addition to the domestic cycles, a wildlife cycle must be considered in the epidemiology of *Echinococcus* in some regions of East Africa.

The present study formed part of an investigation into the epidemiological picture of echinococcosis in Kenya and was undertaken between February 1979 and June 1980. The main objective was to examine the role of wildlife in the transmission of *E. granulosus* in Turkana, where there is one of the highest prevalence rates in man in the world, and to a lesser extent in Masailand where the disease is rare in man but where there were previous records of involvement of wild animals in the cycle of this parasite.

Study Area

The wild animals examined for the specific purpose of this study came from Turkana District in north-western Kenya, and Narok District, Masailand, in south-western Kenya.

The geographical and climatic characters of each are described elsewhere (National Atlas of Kenya, 1970). The Turkana people are Nilo-Hamitic nomadic pastoralists numbering some 165 000 individuals (1969 Census), herding approximately 2·7 million sheep and goats, 0·5 million cattle, 110 000 camels and over 70 000 donkeys (Kenya Rangeland Ecological Monitoring Unit, 1979). In this region almost all of the larger game animals have been eliminated; the smaller animals that remain have a scattered distribution and are few both in number and species diversity.

Although it has been assumed that the main source of infection for man in Turkana is from a domestic cycle, our preliminary observations show that the infection is at present relatively low in cattle (2·0%), goats (0·5%) and sheep (0·2%), but high in camels (33·0%). This infection prevalence in the domestic livestock appears to have altered since the early 1960s because Nelson and Rausch (1963) then reported 'a high cyst rate in the domestic animals' in Turkana. Suggestions for the fluctuating infection rates as a result of ecological changes and possible changes in the parasite will be discussed in a subsequent paper dealing with the domestic cycle.

The incidence in the human population in Turkana is approximately 96 per 100 000 annually (O'Leary, 1976); as this figure represents surgical cases only it underestimates the real incidence of the human disease, which is probably the highest in the world. Nelson and Rausch (1963) reported that 70% of 27 dogs examined in this District harboured adult *Echinococcus*.

Narok District is inhabited mainly by approximately 213 000 Masai (1979 Census) who, like the Turkana, are Nilo-Hamitic nomadic pastoralists. The Masai herd some 526 000 cattle, 388 000 sheep and goats, 19 000 donkeys, but no camels as in Turkana (Kenya Rangeland Ecological Monitoring Unit, 1979). To both tribes, large herds represent wealth, prestige and form the basis of their diet which consists of milk, meat and blood. The Masai live peacefully amongst large herds of wild herbivores, particularly wildebeest, zebra, hartebeest, topi, impala and gazelles which are preyed upon by lions, hyaenas, Cape hunting dogs and jackals. In Kajiado District in Masailand, hydatids occur in 46·7% of cattle, 29·5% of sheep and 9% of goats and yet the disease is rare in humans (reported annual human incidence of 1–2 $100\,000^{-1}$ year^{-1}: Eugster, 1978). Nelson and Rausch (1963) found eight of 16 domestic dogs infected with *Echinococcus* in Masailand, while Eugster (1978) reported a prevalence of 27·3% in 165 dogs examined in Kajiado District.

MATERIALS AND METHODS

The wild carnivores were usually shot at night using a spotlight, bait (usually the carcass of an animal examined earlier in the day) and a 'calling' procedure which consisted of playing a pre-recorded tape of hyaenas over a loudspeaker set on a Landrover. The recording attracted both hyaenas and jackals, sometimes from miles away, and these animals would then turn their attentions to the bait. Hyaenas are rarely seen or heard in Turkana and without such a 'calling' system it would have proved almost impossible to find any. Complete small intestines from the wild carnivores were removed, placed in labelled plastic bags, and stored in a refrigerator overnight. The time interval from killing an animal to the examination of its intestine was eight to ten hours.

The intestine was first rinsed in normal saline, then opened under fresh saline in a large black-bottomed tray. If no *Echinococcus* were seen, the mucosa was scraped and examined by washing and decanting with fresh saline. After being allowed to relax, total worms were counted unless they obviously exceeded 1000 individuals, they were then fixed in 70% alcohol as recommended by Vogel (1957) or in 10% formol saline. Objects which appeared on gross inspection to be either whole worms or segments of *Echinococcus* were kept for microscopic examination. The specimens were stained in Gower's carmine and mounted *in toto*.

Usually ten large and ten small rostellar hooks were measured from each specimen, only those hooks seen in profile being selected.

The lungs, liver, spleen, heart and kidneys of wild herbivorous animals were examined almost immediately after the animals were shot. Any hydatid cysts were examined for the presence of protoscolices and the whole preserved in Bouin's fixative. The fixed material was later sectioned and stained with Delafield's Haematoxylin and Eosin.

Experimental Infections

Three spotted hyaenas and three silver-backed jackals were captured from various locations in Masailand and a litter of four puppies (approximately four weeks old) were purchased in Lodwar, Turkana. In order to exclude any naturally acquired infections each animal received 10 mg kg^{-1} bodyweight of praziquantel (Droncit®, Bayer, Leverkusen, Germany) prior to infection. The animals were starved 21 hours before they were fed a gelatin capsule containing 0·2 ml of approximately 160 000 packed protoscolices obtained from a hydatid cyst removed surgically from a Turkana patient in Lodwar Hospital two days previously. Immediately before administration the material was checked for viability by examining flame cell activity, percentage evagination on a roller at 37°C and the uptake of vital stains, tests which showed the material to have a viability of 93%. The animals were autopsied between 35 and 38 days later, i.e. before worms became ovigerous. The small intestines were removed complete, opened longitudinally, divided into 30 cm lengths from the pylorus and incubated in separate beakers of prewarmed (37°C) Hank's BSS for one and a half hours. The intestines were then scraped and the number of worms estimated either from the volume of sedimented worms after washing, or by counting the worms in five 1 ml aliquots from a volume of 100 ml, if much mucoid material was present; light burdens were counted individually. Only the first 210 cm of the hyaena intestines were processed in this manner. A further 250–300 cm of the intestines were opened and examined by eye.

RESULTS

Turkana

Seventy-six wild carnivores of three species were examined for *Echinococcus* from three locations in north-west Turkana District, near Kakuma, Lakonkai and Lokichokio. These areas were selected because of the extraordinary high incidence of human hydatidosis (African Medical and Research Foundation, 1979), and also because this was an area where some wild mammals were known to occur.

Sixteen spotted hyaenas were collected around Lokichokio township; all were uninfected. The 22 golden jackals (*Canis aureus*) were obtained from Kakuma (0/1 positive), Lakonkai (0/12 positive) and Lokichokio (6/9 positive). The 38 silver-backed jackals were obtained from Kakuma (0/1 positive) and Lokichokio (11/37 positive). Thus of 76 wild carnivores, 17 (22·4%) were found infected with *Echinococcus*. The prevalence rate in all the jackals was 28·3%, or 29% in silver-backed jackals and 27·3% in golden jackals. Details of the infections are given in Table 1.

The morphological data obtained from the golden and silver-backed jackals were compared with material collected from naturally infected dogs from Turkana District. These results are presented in Table 2 and are compared with the results from the Kenyan material obtained by Rausch and Nelson (1963).

In the search for wild intermediate hosts 152 herbivores of five species were examined around the Lokichokio and Kakuma townships in Turkana. Thirty Grant's gazelle

TABLE 1

Wild carnivores examined for Echinococcus *in Turkana*

Echinococcus *infections*	*Species*		
	Silver-backed jackal (Canis mesomelas)	*Golden jackal* (Canis aureus)	*Spotted hyaena* (Crocuta crocuta)
Total animals examined	38	22	16
Positive (light infection) (<200 worms)	7	6	0
Positive (medium infection) (200–1000 worms)	1	0	0
Positive (heavy infection) (>1000 worms)	3	0	0
Total positive	11	6	0

(*Gazella granti*), 51 dik-dik (*Rhynchotragus guentheri*), ten warthogs (*Phacochoerus aethiopicus*), 34 hares (*Lepus* spp.) and 27 ground squirrels (*Xerus* spp.) were all found to be negative for hydatid cysts.

Masailand

One spotted hyaena and one silver-backed jackal examined from the Loita plains in Narok District were negative for *Echinococcus*. Twenty-six animals of six species were examined from the Loita plains in Masailand: 17 wildebeest, one impala (*Aepyceros melampus*), two Grant's gazelle, three Thompson's gazelle (*Gazella thomsoni*), and three topi (*Damaliscus korrigum*). Hydatid cysts were found in the lungs of three wildebeest; two cysts were fertile and each contained a few protoscolices. The fertile cysts measured $2{\cdot}5\times 5{\cdot}5$ cm in diameter whilst the sterile cysts had a diameter of only 2·0 cm. A single topi also harboured a pulmonary infection.

Experimental Infections

None of the spotted hyaenas became infected, in marked contrast to heavy infections produced in the three silver-backed jackals and three of the puppies. The three jackals harboured some 27 130, 29 950 and 2481 strobilae and the infected puppies 140, 4780 and 7780 strobilae. The distribution of the infections in the intestines is shown in Fig. 1.

DISCUSSION

This is the first time that golden jackals have been recorded as definitive hosts of *E. granulosus* in Kenya. The first record of these animals harbouring this parasite was made by Panceri (1868) in Naples. Since then, natural infections in *C. aureus* have been reported from Palestine (Witenburg, 1933), Algeria (Jore d'Arces, 1953), Pakistan (Lubinsky, 1959), Sri Lanka (Dissanaike and Paramananthan, 1960), Lebanon (Dailey and Sweatman, 1965), Iran (Sadighian, 1969) and in Chad, where Troncy and Graber (1969) found one infected jackal of 82 examined.

Although we found that a high percentage (27·3%) of golden jackals harboured *E. granulosus*, the greatest number of worms recovered from any one animal was 44, and the number of worms from the other five infections totalled only 22. No gravid segments were seen in the golden jackal material, although the worms showed normal development and all had testes. No experimental infections were attempted with this species of jackal in

TABLE 2

Comparative measurements (μm) of the rostellar hooks and terminal segments of E. granulosus *from Kenya*

	Terminal segment			*Rostellar hooks*							
		Length of segment		*Total no. of rostellar hooks*		*Large hooks*			*Small hooks*		
Source (and host)	*No. measured*	*Range*	*Mean*	*Range*	*Mean*	*No. measured*	*Range*	*Mean*	*No. measured*	*Range*	*Mean*
Lokichokio (*C. mesomelas*)	27	607–1200	901·5	27–34	30·1	90	26–34	29·4	90	18·8–25·9	22·8
Lokichokio* (*C. aureus*)	21	610– 720	693·8	28–35	31·0	45	26–35	30·0	45	17·7–23·5	20·7
Lokichokio (*C. familiaris*)	40	519–1725	1273	26–37	31·8	89	28–37	31·8	87	20·0–27·1	23·9
Lodwar† (*C. familiaris*)	93	1371–2378	1773	28–36	—	287	32–40	36·0	221	19–31	26·0
Ngong† (*C. familiaris*)	24	1285–2363	1813	—	—	61	31–45	40·0	52	21–39	29·0

*Mature segments only.
†From Nelson and Rausch (1963).

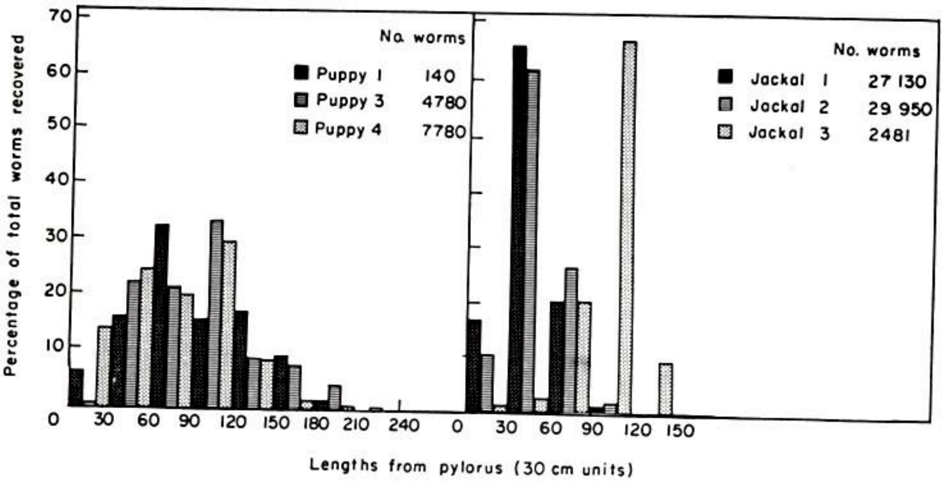

Fig. 1. Distribution of worms in the small intestines of three puppies (left) and three silver-backed jackals (right) infected with *E. granulosus* of human origin.

Kenya, but Witenburg (1933) infected two of four young golden jackals in Palestine. After five weeks the worms were immature, possessed three segments and showed similar development to worms recovered from four of seven control dogs infected with the same source of material. Gravid segments were found in this species by Dailey and Sweatman (1965) from the single jackal they found infected in Lebanon.

The silver-backed jackal appears to be a more important host than the golden jackal in Kenya, and of the 11 found infected, three harboured at least 1000 parasites. Most worms had gravid terminal segments, containing hundreds of shelled eggs.

From the experimental infections in the silver-backed jackal this appears to be rather more susceptible than the dogs to human hydatid material. Earlier experimental infection of a single puppy and jackal (Macpherson and Karstad, 1981) also indicated that the jackal is a good definitive host for the parasite, and Viljoen (1937) and Verster (1965) working in South Africa produced patent experimental infections in silver-backed jackals using protoscolices from cattle, sheep or human hydatid cysts. As our experimental findings, Verster's infections in jackals were usually much heavier than those found in the dogs.

In our experimental animals most of the worms were located in the first 120 cm of intestine from the pylorus, most infections beginning *c.* 10 cm after the pyloric sphincter (Fig. 1).

The first description of a natural infection in the silver-backed jackal was by Nelson and Rausch (1963), who found one of nine animals infected in Kenya. In a South African extensive survey, Verster and Collins (1966) found that 21 of 215 (9·7%) silver-backed jackals harboured the parasite, and Eugster (1978) reported five of 13 (38·5%) of the animals infected in the Kajiado District of Kenya. Three of the five positive animals reported by Eugster had worm burdens in excess of 20 individuals.

The high overall incidence of *Echinococcus* in the jackals is evidence that they may help to perpetuate the transmission cycle in Kenya. However, since no hydatid cysts were found in any of the 152 wild herbivores examined in Turkana it is unlikely that there is a purely wildlife cycle in this District.

The infections found in the jackals in Turkana were probably incidental to their scavenging on domestic livestock carcasses. There is also the possibility that the jackals became infected from the Turkana themselves, for burial of the dead is usually limited to respected old men and married women with children. If this is the case then man in Turkana may not be a dead-end host, as in most other regions of the world, especially since there is such a high prevalence of the disease in man and in view of our evidence that the human parasite from Turkana is highly infective to silver-backed jackals.

Where there is an unusually high prevalence rate of hydatidosis in a local population certain socio-economic and cultural characteristics accentuate the risk for human infection. The very intimate association with dogs which are used as 'nurses' to guard the children and to clear up after vomiting or defaecation was thought by Nelson and Rausch (1963) sufficient to explain the high prevalence in man in Turkana. They also suggested that the Turkana might become infected by eating the intestines of dogs. The Turkana are known to eat practically any kind of meat from both wild and domestic animals, but deny that they eat carnivores (Gulliver and Gulliver, 1953). However, in our experience most Turkana will eat wild carnivores, and they readily took the hyaenas and jackals which we had

Fig. 2. A Turkana woman carrying one of the silver-backed jackals.

killed (Fig. 2). The Turkana regard the intestines of most animals as a great delicacy and eat them with only little cooking. They would have taken the small intestines of the carnivores we had examined, had they been permitted. The consumption of jackals must therefore, on occasion, represent a very real source of infection to some of the Turkana, although they emphatically denied eating dogs.

Rausch and Nelson (1963) stated that the slight morphological differences they found in their Kenyan material could not be considered significant at the species level. The *Echinococcus* specimens we examined from the jackals and dogs shared similar morphological characteristics with the material examined by Rausch and Nelson (1963) (Table 2) and agree with the material described by other authors, which they accepted as *E. granulosus*. However, although the general features were similar in our material to previous material from Turkana, the worms from the naturally infected jackals and dogs were always smaller than those reported by Rausch and Nelson (1963). The finding of very small terminal segments from the golden jackal material is probably due to the fact that they were young segments, not yet ovigerous.

The absence of *E. granulosus* infections from the spotted hyaenas agrees with the findings of Eugster (1978), and also of Verster and Collins (1966), who found no *Echinococcus* in spotted and brown hyaenas (*Hyaena brunnea*); Troncy and Graber (1969) did not find the parasite in striped hyaenas (*Hyaena hyaena*) and Graber and Thal (1980) failed to find the parasite in two spotted hyaenas examined in the Central African Republic. However, *E. granulosus* infections in spotted hyaenas have been reported by Nelson and Rausch (1963), who found three infected animals of 19 examined in Kenya and also by Young (1975), in the Kruger National Park in South Africa. In both instances only a few adult *E. granulosus* were recovered. This fact, coupled with our failure to infect hyaenas as reported here, and also in a previous study with human protoscolices involving three other hyaenas (Macpherson and Karstad, 1981), is evidence that hyaenas, which are phylogenetically widely separated from the Canidae, are poor hosts for the parasite. The spotted hyaena shows a very low density and sporadic distribution in Turkana District, probably being limited mainly to the Mogilla and Songot Mountain ranges around Lokichokio. This also indicates that they have no significance in the transmission cycle of this disease in Turkana District.

Other wild carnivores such as mongooses, the aardwolf (*Proteles cristatus*) and the bat-eared fox (*Otocyon megalotis*), are found in certain parts of Turkana, but none of these seem likely hosts of the adult worm due to their feeding habits (Nelson and Rausch, 1963). Mongooses feed primarily on rodents, but none of the 1674 rodents examined by Nelson and Rausch (1963) in Kenya were infected with *Echinococcus*. Aardwolves and bat-eared foxes are mainly insectivorous.

Members of the cat family are known hosts of other species of *Echinococcus* viz. *E. oligarthrus* and *E. multilocularis*, but they are not regarded as being good hosts for *E. granulosus*, although the lion appears to be an exception. *Echinococcus granulosus* was recorded in lions by Ortlepp as early as 1937. He proposed a new species for the parasite found in the lion, *E. felidis*, subsequently reclassified by Verster (1965) as *E. granulosus felidis*. However, due to the lack of evidence of ecological segregation or marked predator/prey specificity, Rausch (1967) regarded *E. g. felidis* as synonymous with *E. granulosus granulosus*, the nominate subspecies. Other records of infected lions were made by Porter (1943), who found mature specimens in captive animals. Verster and Collins (1966) found five of seven lions in South Africa positive and Rodgers (1974) reported that two of six lions (from the eastern Selous Game Reserve in southern Tanzania) harboured *E. granulosus*.

Dinnik and Sachs (1972) found one infected lion in Narok District and also one of three lions infected in the Ruwenzori National Park, Uganda. These animals harboured sexually mature worms, each with four to six proglottids, the most distal being gravid.

Infected warthogs (11 of 106) and buffaloes (25 of 145) have also been reported from this Park by Woodford and Sachs (1973), who suggest that the warthog is probably the obligate intermediate host for the adult parasite found in lions in the Park. Recently a similar cycle between lions and warthogs has been suggested in the Central African Republic (Graber and Thal, 1980).

Graber and Thal (1980) provide evidence that the lion parasite is a different strain of the parasite from *E. g. granulosus*. They report that apart from morphological differences seen in the parasites obtained from a lion, hydatid material from warthogs and bush pigs was not infective to two Beagles. Thus, the parasite in warthogs and bush pigs may be infective to lions but not to dogs or other canids. Further experimental evidence is now required to establish whether material from warthogs or bush pigs is infective to lions.

That lions are susceptible to experimental infection with material from wild intermediate hosts has been demonstrated by Young (1975), who repeatedly obtained successful infections in lions with liver hydatid cysts from Burchell's zebra. He also reported that *E. granulosus* infections are common in lions in the Park and approximately 60% of the zebras found in the Park harbour hydatid cysts. He considers therefore that the zebra is probably the most important intermediate host of *E. granulosus* for lions in this Park. Other wild intermediate hosts found in the Kruger National Park include hippopotamus (McCully *et al.*, 1967), buffaloes (Basson *et al.*, 1970) and impala (Young, 1975), all of which may be susceptible to the strain of *E. granulosus* found in the lion.

In Kenya, lions may be important in a wildlife cycle in Masailand, since they and their wild prey species, particularly wildebeest, can both harbour the parasite in this area (Dinnik and Sachs, 1972; Eugster, 1978). However, in Turkana, there are so few lions that they probably do not play any important role in the transmission of the disease.

Cape hunting dogs, now very rare in Masailand and probably extinct in Turkana, appear to be very good hosts of the parasite. Nelson and Rausch (1963) were the first to report *Echinococcus* in this species, finding three out of four animals infected in Kenya. Verster (1965) changed the earlier classification of Ortlepp (1937) of the parasite found in Cape hunting dogs from *E. lycaontis* to *E. granulosus lycaontis*, which, like *E. g. felidis*, was regarded by Rausch (1967) as synonymous with *E. g. granulosus*. Unfortunately, there are now so few Cape hunting dogs in the wild that it was not possible to determine experimentally the suitability of this carnivore as a definitive host for *Echinococcus* of Kenyan origin.

Our findings that two of the three hydatid cysts obtained from three of the 17 infected wildebeest examined in Narok District were fertile, provides further evidence that the main food animals of the lion in this area harbour cysts of the parasite. Previous records include those of Nelson and Rausch (1963), who reported one out of 17 wildebeest harbouring fertile cysts; Schiemann (1971): two out of 450 (0·4%); Sachs (1976): three out of 70 positive and Eugster (1978), who found 69 out of 567 (12·2%) wildebeest positive. The lungs were the usual predilection site of the cysts, most of which were fertile (Nelson and Rausch, 1963; Eugster, 1978).

Wildebeest, giraffe (*Giraffa camelopardalis*) and warthog harbour fertile cysts in the Serengeti, which is adjacent to Narok District (Sachs and Sachs, 1968; Dinnik and Sachs, 1969). Myers *et al.* (1970) reported hydatid cysts in two young captive baboons (*Papio* sp.) imported from Kenya. However, baboons probably play little part in the transmission of the disease in nature as none of 180 baboons examined by Nelson and Rausch (1963) were found to be infected. One buffalo (*Syncerus caffer*), one blue duiker (*Cephalophus monticola*), two of 24 impala, two of 26 Grant's gazelle and two of 38 hartebeest (*Alcelaphus buselaphus cokii*), were found to harbour cysts in Kajiado District (Eugster, 1978).

In Masailand it seems likely that lions, and to a much lesser extent Cape hunting dogs, are the true definitive hosts in a predator–prey relationship with the wild herbivores as intermediate hosts. The identification of the parasite found in these two definitive hosts must therefore remain open to further investigations, especially since so many of their prey species have been found to harbour hydatid cysts and in view of the fact that hydatid material from warthogs and bush pigs may not be infective to dogs. Jackals as scavengers are important secondary hosts, capable of disseminating the parasite. The domestic cycle between dogs and domestic animals probably evolved at a later date with possible differences in the infectivity of the parasite for man. This may readily arise due to the potential for genetic selection for new strains of the parasite in a single generation because of the mode of reproduction of the parasite (Smyth and Smyth, 1964). A succession of re-introductions must have also taken place during the more recent period of colonization. The parasite in Turkana has probably escaped from a completely wildlife cycle and here the maintenance of the infection must depend on the scavenging of dogs and jackals, on infected domestic animals and possibly also on infected humans (Fig. 3).

Further studies are obviously necessary in both the wild and domestic animals in different parts of Kenya. Initial isoenzyme studies indicate that there may be an unusually complex 'strain' situation in this region (McManus and Macpherson, 1980).

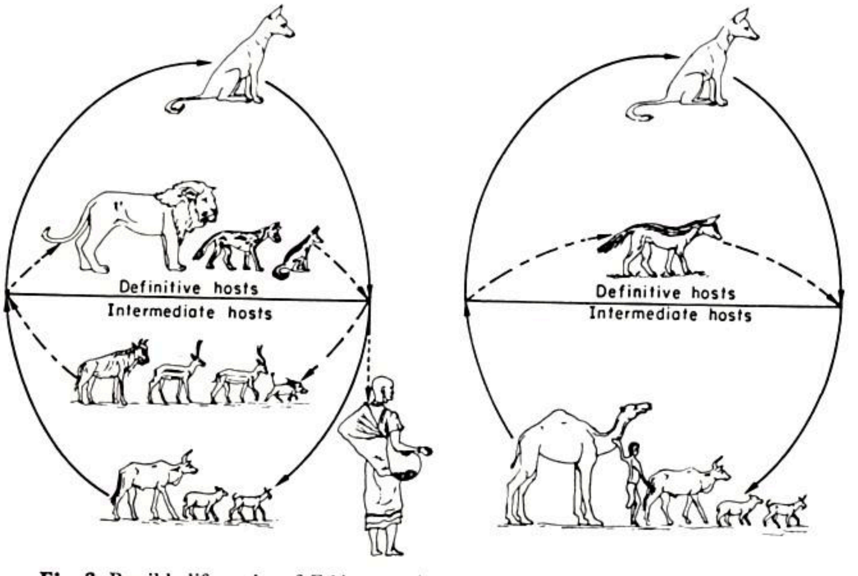

Fig. 3. Possible life cycles of *Echinococcus* in Masailand (left) and Turkana (right).

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