Acta vet. scand. 1979, *20*, 583—594.

From the Institute of Parasitology, College of Veterinary Medicine, and the National Veterinary Institute, Uppsala, Sweden.

PRESENCE OF TRICHINELLA SPIRALIS IN FREE-LIVING RED FOXES (VULPES VULPES) IN SWEDEN RELATED TO TRICHINELLA INFECTION IN SWINE AND MAN

By

Otto Ronéus and *Dan Christensson*

RONÉUS, OTTO and DAN CHRISTENSSON: *Presence of Trichinella spiralis in free-living red foxes (Vulpes vulpes) in Sweden related to trichinella infection in swine and man.* Acta vet. scand. 1979, *20*, 583—594. — One thousand one hundred and fifty-one free-living foxes (Vulpes vulpes) from different parts of Sweden were investigated. Totally 19.6 % were infected with trichinella. Infected foxes were found in all counties except the geographically isolated island of Gotland. In the different counties 6—48 % of investigated foxes were infected.

Trichinella was more common in old foxes than in young, 40 % and 11 %, respectively. Regarding male and female, however, the frequency was the same.

The number of trichinella per g of muscle varied between 0.05 and 200. Less than 1.0 trichinella larva per g muscle was established in 27.3 % of the foxes, between 1 and 49.9 trichinella larvae in 69.3 % and 50 or more trichinella larvae per g muscle in 3.4 % of the foxes. The number of trichinella larvae per infected fox was roughly the same in both sexes as well as in different age groups.

The potential danger of transmitting trichinella from foxes and other carnivores to swine and man is pointed out.

The high frequency of trichinella in foxes, 19.6 %, was compared to the very low frequency in swine, 0.00018 %, and in man, 0.00003 %.

Trichinella spiralis; fox; swine; man; prevalence.

In Sweden wild carnivores, especially red foxes, are often observed to be infected with Trichinella spiralis. As the foxes seem to be a potential danger of infection to swine and thus also indirectly to man, an investigation of the occurrence of trichinella in free-living foxes has been regarded as urgent.

The presence of trichinella in red foxes from different parts of the country and of different sexes and ages has been investigated. The cases of trichinella in foxes have been compared to the present situation of trichinella in swine and man.

MATERIAL AND METHODS

Foxes

A total of 1151 free-living foxes (Vulpes vulpes) has been investigated. The foxes were mainly killed during the hunting season from October to March. They originate from all 24 counties of Sweden. Their geographical distribution is shown in Table 1. The sex has been established in 591 of the foxes: 294 were males and 297 were females.

Determination of age was performed on 588 foxes, showing that 298 were young, about 1 year old; 260 were of middle-age; and 30 were old, approx. 6 years of age or older.

Trichinella investigation

As a rule the masseter and thigh muscles have been examined. Methods used have been trichinoscopy and, on the material which had not been deep-frozen earlier, a digestion method.

Trichinoscopy was performed in all cases. About 0.5 g from every muscle sample was investigated. The samples were divided into small pieces, pressed between 2 glasses to form a thin film and the trichinella larvae were detected by means of microscopy. In the digestion method about 10 g of the masseter and 10 g of the thigh, always 20 g together, were investigated. The muscle samples were atomized in 100 ml of digestion fluid during 5 min in an Automix. The digestion fluid was composed of 10 g pepsin (2000 FIP-u/g), 30 ml HCl conc., and 1000 ml aqua fontana. This muscle suspension was then mixed with an additional 400 ml of digestion fluid. The sample was incubated at 37°C for 16 to 18 h. After settling for 60 min the supernatant was sucked up and the sediment was washed in about 500 ml of cold water. After a new settling the sediment, about 50 ml, was distributed in Petri dishes in which the bottoms were divided into a 1 cm^2 pattern. The sample was investigated under a magnifying glass and the number of trichinella larvae per g of muscle tissue was counted.

Trichinella in swine and man

Reports of the annual frequency of trichinella cases in slaughtered swine and in man during the years 1970 to 1977 have been received from The Swedish National Food Administration and the Department of Epidemiology at the National Swedish Bacteriological Laboratory. The findings in swine are based on the usual trichinoscopy technique and the findings in man are based on serology.

RESULTS

The frequency of trichinella in foxes

Of the 1151 investigated foxes, 37 came from the geographically isolated island of Gotland which is presumed to be free from trichinella. Thus from the remaining areas of Sweden, 1114 foxes have been investigated, and 218, or 19.6 %, were found to be infected with trichinella.

Geographically the trichinella cases were distributed all over the country, and trichinella in foxes was found in all counties except Gotland. Local variations of the frequency of infected foxes seem to occur. The highest frequency was seen in the

Table 1. Cases of trichinella infection in free-living foxes in different counties.

County	Investigated number	Infected		County	Investigated number	Infected	
		number	%			number	%
B Stockholm	65	13	20	O Göteborg-Bohus	33	10	30
C Uppsala	30	3	10	P Älvsborg	51	13	26
D Södermanland	18	6	34	R Skaraborg	38	8	21
E Östergötland	47	10	21	S Värmland	46	5	11
F Jönköping	85	26	31	T Örebro	36	7	20
G Kronoberg	36	6	17	U Västmanland	18	8	44
H Kalmar	62	13	21	W Kopparberg	54	14	26
Öland	18	1	6	X Gävleborg	31	13	42
an island of H				Y Västernorrland	49	9	18
I Gotland	37	0	0	Z Jämtland	47	3	6
K Blekinge	21	10	48	AC Västerbotten	48	10	21
L Kristianstad	35	9	26	BD Norrbotten	175	12	7
M Malmöhus	52	3	6				
N Halland	19	6	32				

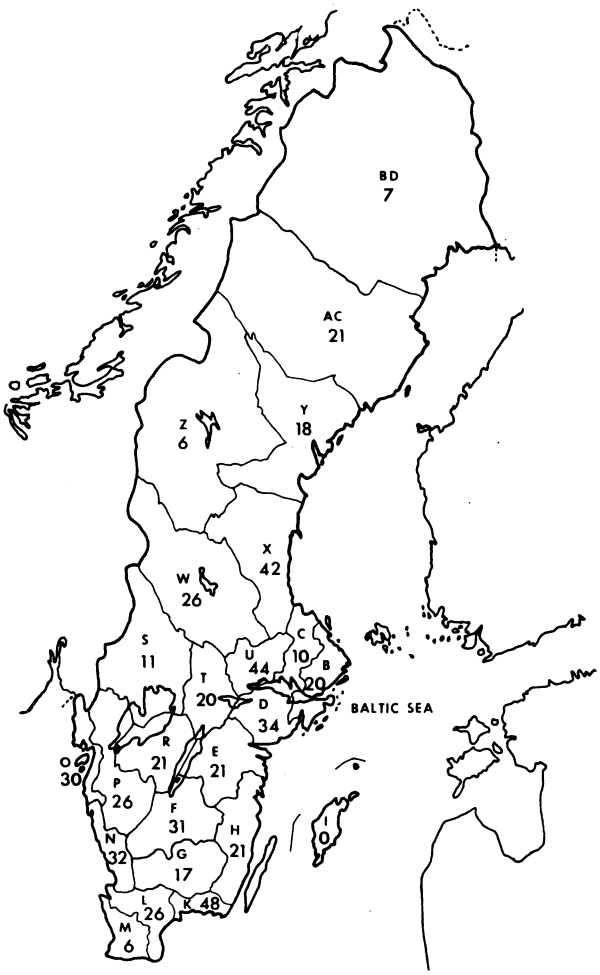

Figure 1. Map of Sweden. The letters indicate county registration, see Table 1. The figures indicate the frequency of trichinella infected foxes in percentage.

counties of Göteborg-Bohus, Halland, Södermanland, Gävleborg, Västmanland and Blekinge where 31—48 % of the foxes were infected. The lowest frequency was found in the counties of Malmöhus, Jämtland and Norrbotten where 6—7 % were infected. The frequency in the remaining counties was between 7 and 30 %. The distribution of trichinella cases in the different counties is shown in Table 1 and Fig. 1.

Presence of trichinella in males and females

Among the 591 sex-determinated foxes, trichinella occurred in 19 % of the males and in 15 % of the females (Table 2). The difference between the 2 sexes was not significant, $P = 1.08$.

Table 2. Presence of trichinella in foxes according to sex.

	Investigated	Infected	
		number	%
Males	294	55	19
Females	297	45	15

Presence of trichinella in different age groups

Among the 588 age-determinated foxes trichinella occurred in 11 % of the young, in 19 % of the middle-aged, and in 40 % of the old animals (Table 3). The investigation indicates that old foxes are more often infected than young ones. The difference is significant, $P < 0.01$.

Table 3. Presence of trichinella in foxes according to age.

	Investigated	Infected	
		number	%
Young	298	34	11
Middle-aged	260	49	19
Old	30	12	40

Infection level of the foxes

Of the 218 infected foxes, 176 had not been deep-frozen, and in these the number of trichinella larvae therefore could be investigated by using the digestion technique. The infection level varied (Table 4).

An infection level of 1—49.9 larvae per 1 g of muscle tissue occurred in most of the infected foxes, 69.3 %. A low infection,

Table 4. Number of trichinella per 1 g of muscle tissue in 176 foxes.

Number of trichinella per 1 g muscle	Foxes	
	number	%
<1.0	48	27.3
1.0—49.9	122	69.3
≥ 50.0	6	3.4

less than 1.0 larva per 1 g, was observed in remarkably many cases, 27.3 %, the fewest number of larvae per 1 g being 0.05. An infection level of 50 or more larvae per 1 g was found in 3.4 % of the foxes, and the largest number of larvae per 1 g muscle tissue being 200.

Notably, in 26 of the 176 investigated foxes, of which 24 had less than 1 trichinella larva per g of muscle tissue, no larva was found by trichinoscopy. These low levels of infection could only be detected by using the digestion technique.

Number of trichinella per 1 g of muscle tissue in males and females

Among the 176 infected foxes, determination of the sex was made in 68 cases, of which 36 were males and 32 females. The infection level of the different sexes is shown in Table 5. No obvious difference in the infection level between the sexes is noticed in this material.

Table 5. Number of trichinella per 1 g of muscle tissue in 36 males and 32 females.

Number of trichinella per 1 g muscle	Number of foxes	
	males	females
<1.0	10	4
1.0—49.9	24	27
≥50.0	2	1

Number of trichinella per 1 g of muscle tissue in different age groups

Determination of age could be performed only on 60 of the 176 infected foxes, of which 25 were young, 30 of middle-age,

Table 6. Number of trichinella per 1 g of muscle tissue in 25 young, 30 middle-aged and 5 old foxes.

Number of trichinella per 1 g muscle	Number of foxes		
	young	middle-aged	old
<1.0	12	9	1
1.0—49.9	13	18	4
≥50.0	0	3	0

and 5 were old. The infection level of the different age groups is shown in Table 6. The difference between the age groups is not significant, P = 1.61.

Presence of trichinella in animals other than free-living foxes

At the National Veterinary Institute the presence of trichinella has been shown in the free-living badger, polecat, ermine, marten, lynx, mink and rat; in farmed foxes and minks; in dogs and cats; and in the tiger, lion, polar bear, and wolf from zoological gardens.

To be noted is that none of 20 examined free-living brown bears had trichinella.

The investigated material, however, does not admit to establish the degree of frequency of trichinella in these species of animals.

Presence of trichinella in slaughtered swine

The number of infected swine at the trichinella control during recent years is shown in Table 7. During the years 1970—1977 about 29.3 mill. swine have been slaughtered and inspected. Trichinella has been observed in 52 or in 0.00018 %.

Table 7. Number of slaughtered swine infected with trichinella, observed at meat-inspection.

Year	1970	—71	—72	—73	—74	—75	—76	—77
Number mill. slaughtered swine	3.2	3.5	3.8	3.5	3.7	3.7	3.9	4.0
Number of swine with trichinella	4	3	14	13	5	5	3	5

Presence of trichinella in man

The population in Sweden has been about 8 mill. during the years 1970—1977. The frequency of trichinella infection during these years is shown in Table 8. During the years 1970—1977, a yearly average of 2.1 cases of trichinella infection occurred, i.e. 0.00003 % of the whole population.

Table 8. Number of clinical cases of trichinella infection in man.

Year	1970	—71	—72	—73	—74	—75	—76	—77
Clinical cases	5	7	0	2	0	0	0	3

DISCUSSION

Free-living foxes are considered to be of great importance as reservoirs of trichinella. Therefore, in many countries, the frequency of infected foxes has been investigated. The investigations are, in some cases, based on a low number of foxes or from a limited area of the country. The frequency seems, however, to vary in different areas. In Switzerland 15 % of investigated foxes are reported to be infected with trichinella, in Poland 7.3 %, in Czechoslovakia 22.7 %, in Romania 22.8 %, in Bulgaria 35.3 %, in Yugoslavia 12.9 %, in Italy 17 %, in the USSR 17.7 %, and in Iowa in the USA 6.4 % (*Gould* 1970).

A low frequency of trichinella in foxes is reported from Germany, 1.9 % (*Lehmensick* 1970) and in Holland, 3.1 % (*Sluiters et al.* 1972). In Greenland 18 % of the arctic foxes were infected (*Madsen* 1961). Regarding the neighbouring countries of Sweden, in Norway 22.4 % (*Iversen* 1948) and 20.6 % (*Hauge* 1969) of the free-living foxes were infected, in Finland 3.8—15.8 % (*Freemann* 1964) while in Denmark less than 0.1 % were infected (*Clausen & Henriksen* 1976).

In relation to these figures, Sweden has a high frequency of infected foxes. Local investigations have earlier shown frequencies between 8.5 and 58.5 % (*Ekstam* 1964). The present investigation shows a frequency of 19.6 %.

Foxes are common all over Sweden and are coveted game. During years when there are a normal number of foxes, about 60 000 to 70 000 are shot, corresponding to a fox population of about 200 000 animals (*Borg* pers. commun.). Thus, with an injection frequency of 19.6 %, about 40 000 of the foxes would be infected with trichinella.

Foxes all over Sweden are infected, with the exception of the geographically isolated island of Gotland. The frequency of infected foxes in the different counties is indeed presented without considering the age of the foxes and is also founded on a relatively small number of foxes, but the differences are so distinct that it can be presumed that a local variation occurs.

These local variations are difficult to explain. The low frequency in Malmöhus county, 6 %, probably depends on the fact that this county is a highly cultivated area as well as being rich in small game such as hares, rabbits and pheasants which are desirous prey for foxes. The abundance of small game can reduce the tendency of cannibalism, which is considered to be the main cause of the high frequency of trichinella in foxes, and can thus explain the low frequency of trichinella in this county.

From an epidemiological point of view it would be interesting to determine whether the presence of trichinella and the degree of infection are concentrated to certain groups of foxes. Concerning sex, there does not seem to be any differences. Concerning different age groups, however, old foxes were infected in a higher degree, 40 %, than young ones, of which 11 % were infected. This obviously depends on the fact that the older foxes have had more occasions to become infected and that the tendency of cannibalism is probably more pronounced among older foxes.

The degree of infection, i.e. the number of trichinella larvae per g of muscle, varied. It is to be noticed that a remarkable number of foxes showed low infection, i.e. they had less than 1 trichinella larva per g of muscle. The variations between 0.05 and 200 trichinella larvae per g of muscle can depend on the fact that the animals studied had eaten different quantities of different infected meat.

This investigation did not give any proof that the degree of infection was dependent on the age of the animals in contrast to the infection frequency, which obviously seems to be dependent on the age.

Foxes are definitely the most important reservoir for trichinella in this country. It is to be observed that even other animals can be trichinella carriers, e.g. the badger. In the meat inspection of 4639 badgers in 1942—1943 trichinella was found in 2 % of the animals (*Ekstam*). In rats trichinella is, however, rare. In a separate investigation of 476 rats from different parts of the country, not a case of trichinella was found (*Hülphers & Henricson* 1943).

A high frequency of infected foxes means a high potential risk of transmission of the infection. The risk that new foxes will be infected increases if the killed foxes are left in the forest after skinning. Sometimes the bodies of the foxes are brought to a farm, thrown on a dunghill or hung up, as food for small

birds near the swine house. This obviously creates a risk of transmitting the infection to farm animals.

In order to reduce the transmission of trichinella within the fox population as well as the risk of transmitting trichinella from foxes to swine, it is important that the dead foxes will be disposed of in a safer way. They should not be left in the forest, but instead be taken home and there be destroyed in such a manner that they are unavailable to swine, as well as to cats or rats, which can indirectly transmit the infection to swine.

In swine trichinella is very rare in Sweden. It is only found in 0.00018 % of slaughtered swine, in spite of the fact that free-living foxes show a high frequency of infection. The methods of swine production in this country can partly account for the low frequency of trichinella. Slaughter swine as well as sows, boars and young pigs are nowadays more usually kept indoors. The swine will therefore get less opportunity to feed from infected foxes and other wild animals. Swine breeders, however, should not ignore the potential danger of trichinella being transmitted by foxes as well as badgers and other wild animals.

In man trichinella infection is also rare in this country. It certainly depends on the low frequency of infection in swine and on the fact that significant porcine infections are sorted out by the routine trichinella control. The trichinella infection of foxes, however, also constitutes a danger for man. The direct danger of infection by eating fox and badger meat, if this should happen, is of course important. There is also a reason for pointing out the danger when eating wild boar meat.

Present circumstances show that a very low frequency of trichinella can occur in swine, 0.00018 %, and in man, 0.00003 %, while at the same time a very high frequency can occur in foxes, 19.6 %. This fact undoubtedly shows that in Sweden the risk of transmitting trichinella from foxes to swine and man is low, but the risk should not be neglected.

ACKNOWLEDGEMENTS

Thanks are due to Mrs Vigdis Holta for valuable technical assistance.

REFERENCES

Borg, K.: Personal communication, National Veterinary Institute, Stockholm 1978.

Clausen, B. & Sv. Aa. Henriksen: The prevalence of Trichinella spiralis in foxes (Vulpes vulpes) and other game species in Denmark. Nord. Vet.-Med. 1976, *28*, 265—270.

Ekstam, M.: Trikinos. (Trichinosis). Svensk Vet.-Tidn. 1964, *16*, 11—17; 39—49.

Freeman, R. S.: Leveå heisimato ja Trikiini luonnonvaraisissa ketuissa suomessa. (Broad fish tape-worm and trichina worm in wild red foxes in Finland). Finsk Vet.-T. 1964, 7—*8*, 279—282.

Gould, S. E.: Trichinosis in Man and Animals. Charles C. Thomas 1970, Springfield, Illinois.

Hauge, S.: Trikinosens epidemiologi i Norge. (The epidemiology of trichinosis in Norway). Medlemsbl. norske Vet.-Foren. 1969, *21*, 325—331.

Hülphers, G. & T. Henricson: Undersökningar på förekomst av infektionsämnen och trikiner i råttor. (Studies on the occurrence of microbes and Trichinella in rats). Svensk Vet.-T. 1943, *48*, 197—210; 245—254.

Iversen, M.: Trikinosens utbredelse og bekjempelse i Norge. (The occurrence and controlling of Trichinella in Norway). Norsk Vet.-T. 1948, *60*, 303—309.

Lehmensick, R.: Einige Daten über die Epidemiologie der Trichinellose in West-Deutschland (Bundesrepublik). (Some information of the epidemiology of trichinosis in West-Germany). Wiadomosci parazytologiczne T. XVI, 1970, No. 1. Proc. second int. conf. on trichinellosis, Wroclaw, June 26—28, 1969.

Madsen, H.: The distribution of Trichinella spiralis in sledge dogs and wild mammals in Greenland (Under a global aspect). Meddelelser om Grønland 1961, bd 159 nr. 7.

Sluiters, J. E., E. J. Ruitenberg & C. J. Vermeulen: Vorslag over onderzoekingen naar het voorkommen van Trichinella spiralis in Nederland. (Studies on the occurrence of Trichinella spiralis in the Netherlands). T. Diergeneesk. 1972, *97*, 1386—1393.

SAMMANFATTNING

Förekomst av trikiner (Trichinella spiralis) hos fritt levande rödräv (Vulpes vulpes) i Sverige i relation till påvisade trikinfall hos svin och människa.

1151 fritt levande rävar (Vulpes vulpes) från olika delar av Sverige undersöktes. Av dessa var 19,6 % infekterade med Trichinella. Infekterade rävar förekom i alla landskap utom på Gotland. I de olika länen var 6—48 % av de undersökta rävarna infekterade.

Hos gamla rävar var trichinos vanligare än hos unga, 40 % resp. 11 % var infekterade. Däremot var trikiner lika vanliga hos han- som honrävar.

Antalet trikiner per gram muskulatur varierade mellan 0,05—200. Mindre än 1,0 trikin per gram muskulatur påvisades hos 27,3 % av rävarna, mellan 1 och 49,9 trikiner hos 69,3 % och över 49,9 trikiner

per gram muskulatur hos 3,4 % av rävarna. Antalet trikiner per individ var i stort lika hos de båda könen och även inom olika åldersgrupper.

Den potentiella risken för spridande av trichinos från rävar och andra carnivorer till svin och människa påpekas. Den höga frekvensen trikinfall hos rävar, 19,6 %, jämföres med de mycket låga frekvenserna hos svin, 0,00018 % och hos människa, 0,00003 %.

(Received April 10, 1979).

Reprints may be requested from: Otto Ronéus, the National Veterinary Institute, S-750 07 Uppsala, Sweden.