

Trichinella sp. in polar bears from Svalbard, in relation to hide length and age

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Larsen, T. & Kjos-Hanssen, B. 1983: *Trichinella* sp. in polar bears from Svalbard, in relation to hide length and age. *Polar Research 1* n.s., 89–96. Oslo.

Diaphragma and masseter muscles from 376 polar bears (*Ursus maritimus*), 252 ringed seals (*Phoca hispida*), 84 bearded seals (*Erignathus barbatus*), and 77 arctic foxes (*Alopex lagopus*) from Svalbard were examined for *Trichinella*. Infection rates in polar bears varied between 23 and 58%, and between 3 and 67% in arctic fox. None of the seals were infected. *Trichinella* in polar bears is probably transferred through cannibalism and scavenging upon polar bear carcasses. Infection rate in arctic fox was high when they preyed upon polar bear carcasses before polar bear hunting was prohibited in 1973. A low infection rate seems more natural when such prey is not available. No difference could be found in infection rate between male and female polar bears. There is only a slight increase in infection rate with age, as calculated from hide lengths, and many adult animals remain uninfected. Geographical isolation of polar bear populations may explain differences in *Trichinella* infection rates between bears from arctic America and arctic Europe. Possible explanations are that discrete polar bear populations have different food habits, or that they are exposed to different *Trichinella* strains.

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Introduction

Trichinellosis in free-roaming polar bears (*Ursus maritimus*) was first described by Parnell (1934). Later research has shown that *Trichinella* has a circumpolar distribution and that the parasite has occurred in polar bears for a long period of time (Jepsen 1968). Bears can be infected by eating other bears or bear carcasses, although some authors have claimed that polar bears receive trichinellosis mainly from eating seals or walrus (Ozeretskoykaya & Uspensky 1957; Manning 1960; Lentfer 1976). The objective of this paper is to discuss probable infection pathways for *Trichinella* in arctic ecosystems, to evaluate possible differences in *Trichinella* infection rates in relation to sex and age of polar bears, to discuss the effect of various *Trichinella* strains on polar bears and other species, and to compare *Trichinella* infections in polar bears from various regions in order to differentiate between populations.

Material and methods

The material consisted of 342 diaphragma and 34 masseter muscle samples from 376 different polar bears collected between about 1950 and 1970, diaphragma samples from 252 ringed seals (*Phoca*

hispida) collected in 1981 and 1982, and from 84 bearded seals (*Erignathus barbatus*) from 1954. Seventy-seven diaphragma samples from arctic foxes (*Alopex lagopus*) collected between 1954 and 1980 were also studied. The polar bear samples were either dried or preserved in 70% ethyl alcohol or in 4% formaldehyde. The seal and fox samples were kept frozen at 20°C below zero. Thirty polar bear samples were from animals whose age was determined by sectioning and counting the teeth cementum layers. One hundred and sixty-seven samples were from bears with known hide length. Trichinellosis was studied by means of the compression method: ca. ½ g muscle tissue was squeezed between glass plates to a thin layer which permitted inspection under a 50× enlargement microscope or trichinoscope, and counting of *Trichinellas* in the sample. Dried and alcohol preserved samples were softened in water, and formaldehyde preserved samples were softened and clarified with a 5% KOH solution (Roth 1949) prior to compression. After such treatment, *Trichinella* capsules could be identified (Fig. 4). Frozen samples and questionable formaldehyde samples were studied by the digestion technique where the magnet stirrer method was used (Framstad 1980).

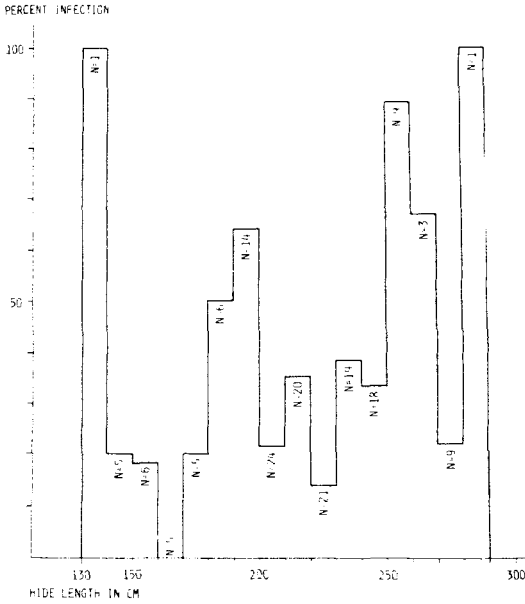


Fig. 1. Percentage of polar bears from Svalbard infected by *Trichinella* sp. versus hide lengths.

Age determination and growth curves (Figs. 2 and 3) are based on body measurements and tooth cementum age determinations for 82 male and 83 female polar bears captured alive and studied in Svalbard between 1967 and 1980. Hide lengths were calculated by converting measured zoologi-

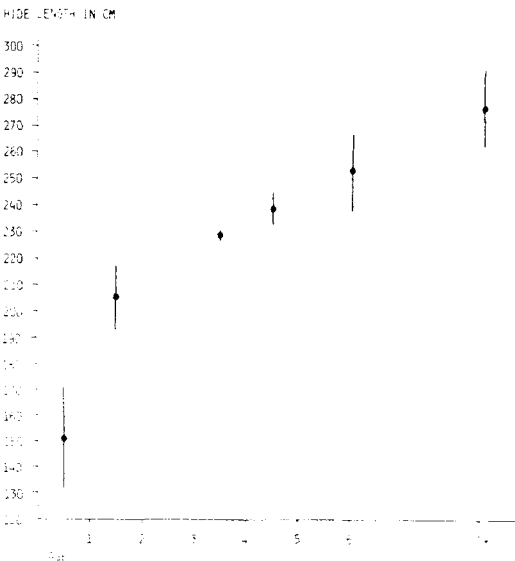


Fig. 2. Growth curve of female polar bears from Svalbard. Age versus hide lengths (N = 83).

cal lengths with a factor of 1.18 for males and 1.23 for females. The correction factors have been calculated from Lønø (1970), who gives zoological lengths and hide lengths for 43 male and 34 female polar bears from Svalbard. Bears with hides between 130 and 229 cm were classified as cubs or juveniles, i.e. bears before they are weaned and leave their mother in their third year of life. Bears with hide lengths between 230 and 310 cm are classified as subadults or adults. No further attempt was made to distinguish between age groups because of the amount of overlap in hide lengths.

Results

The results of the *Trichinella* investigations in the total of 376 polar bear samples are given in Table 1. Table 2 shows the *Trichinella* infection in 30 bears aged by tooth cementum layer counts from Ryke Yseøyanne 1967-69. In Table 3, the occurrence of *Trichinella* in polar bears is plotted against hide length of intervals of 10 cm. Figures 2 and 3 show female and male growth curves. Eighty-six bears had hide lengths less than 230 cm and are classified as cubs and juveniles. Of these 28 had trichinellosis, giving an infection rate of 33%. Of the remaining 81 bears classified as subadults or adults, 29 had trichinellosis, i.e. an infection rate of 36%. The percentage number of polar bears with trichinellosis versus hide lengths at 10 cm intervals is shown in Fig. 1. The incidence of *Trichinella* infection in different polar bear samples varies between 23 and 58%, with an average of 32.7%. Four of the six different sample sets had an infection rate between 23 and 33% (Table 1). The infection rate of males was not significantly different from that of females (Tables 2 and 3). There was no evident increase in infection rate with increasing hide length (Fig. 1). Of the 77 arctic fox samples, 10 of a total of 15 from Tjuvfjorden in 1954-55 were infected, giving an infection rate of 67%. The remaining 62 fox samples were from northwest Spitsbergen in 1979. Only 2, or 3%, were infected. None of the 252 ringed seal samples nor 84 bearded seal samples were infected by *Trichinella*.

Discussion

Polar bears are typical carnivores, and 90% of their diet consists of seals (Lønø 1970; Larsen

Table 1. Occurrence of *Trichinella* sp. in polar bear diaphragma samples from different localities in Svalbard between 1950 and 1970.

Locality	Year	No. of samples	No. of positive	% inf.	Sampled by
Bjørnøya	ca. 1950	12	7	58	Zool. mus. Oslo
Tjuvfjorden	1954	66	32	48	O. Lønø
Ryke Yseøyane	1967-69	104	34	33	K. Torsvik
Hopen	1966-67	57	13	23	Hopen crew
Hopen	1969-70	40	10	25	Hopen crew
Halvmåneøya/ Tjuvfjorden	1969-70	63 ¹	16	25	P. Johnsen, A. Strand and S. Ytreland
Sum/average		342 ¹	112	32.7	

1. In addition, 34 masseter muscle samples were studied, of which 6 were infected.

1978). Seals, and particularly ringed seals, which are the polar bears' main prey animal, eat mainly plankton, fish or benthic organisms, in which *Trichinella* cannot develop. The absence of *Trichinella* in the seals in this study is in agreement with the observations of Thorshaug & Rosted (1956), who did not find trichinellosis in any of 1556 samples from various arctic seal species. Madsen (1961) found only one infected ringed seal in 1775 animals from Greenland, and Fay (1960) only two in 300 from Alaska. Trichinellosis in seals can be due to an occasional eating of

remains of an infected polar bear carcass. It has been experimentally confirmed that *Trichinella* can be transferred by amphipods and fish (Fay 1960; Ozeretskovskaya *et al.* 1969). Trichinellosis in seals must be regarded as a curiosity and cannot be taken to explain the high infection rate in polar bears, because it is unlikely that crustaceans or fish play any role in the transfer of the parasite in nature.

Various studies of walrus (*Odobenus rosmarus*) give a *Trichinella* infection rate between 2% (Born *et al.* 1982) and 9% (Thorshaug & Rosted 1956). The walrus is a bottom feeder which lives mainly from molluscs. There are reports, however, about walruses which occasionally eat meat or hunt for seals and other mammals (Degerbøl

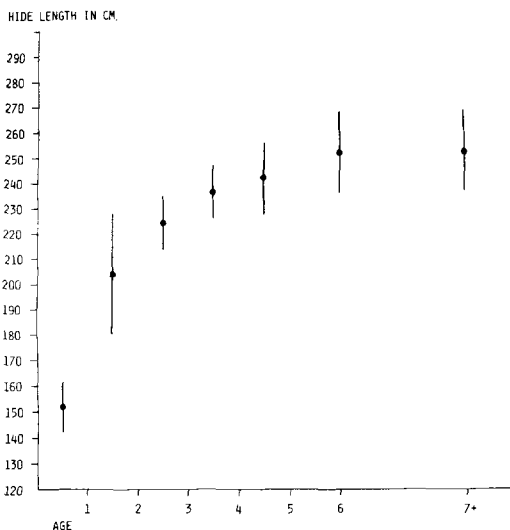


Fig. 3. Growth curve of male polar bears from Svalbard. Age versus hide lengths (N = 82).

Table 2. Trichinellosis in 30 polar bears from Ryke Yseøyane, Svalbard 1967-69, aged by tooth cementum layer counts.

Age	No. of ♂♂ examined	Infected	No. of ♀♀ examined	Infected
1	2		2	
2	3	1	1	
3	1		4	1
4	3	1	1	
5			1	1
6			2	1
7	2	1	1	1
8			2	
9			1	
11	1			
12	1			
13	1		1	1
Sum	14	3	16	5

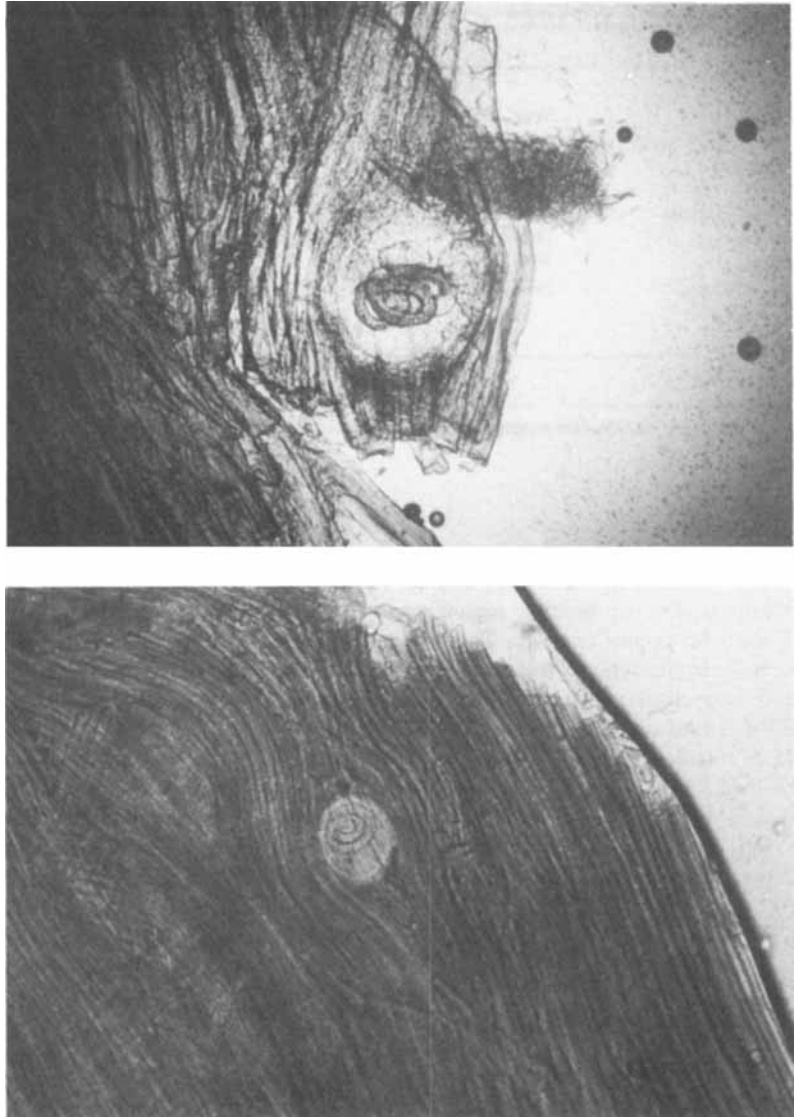


Fig. 4. *Trichinella* capsules in formaldehyde preserved polar bear diaphragma samples compressed after treatment with a 5% KOH solution (photo H. Ulveseter).

& Freuchen 1935; Fay 1960). Thus, trichinellosis in walrus can be explained by its occasional eating of polar bear meat or dog meat which is infected. On the other hand, the walrus is not normally a prey animal for polar bears, unless it eats carcasses from walrus hunts (Kulstad 1970; Lønø 1970). The walrus was very rare in Svalbard waters between 1945 and 1970 (Larsen & Norderhaug 1974). All walrus hunting in Norwegian waters was prohibited in 1952. Walruses or walrus carcasses have therefore not been available as an important food resource for polar bears in Svalbard when this study was made, and cannot

explain *Trichinella* infection rates. Arctic foxes are not common prey animals for polar bears. Trichinellosis in arctic fox has been described from all parts of the Arctic. Rausch (1970) estimated that about 10% are infected; Roth (1949) found an infection rate of 3% in Greenland. The infection rate in the fox material from Svalbard in 1979 is comparable with their findings. In 1954-55 foxes from Tjuvfjorden had a comparatively very high *Trichinella* infection rate, which can be explained by their scavenging upon polar bear carcasses. During this period there was an extensive polar bear set gun harvest in that area,

Table 3. Trichinellosis versus hide lengths in polar bears from Svalbard.

Hide length	No. of ♂♂		No. of ♀♀		No. of ♂♂ ♀♀ combined		% infected
	Exam.	Inf.	Exam.	Inf.	Exam.	Inf.	
140-149	0	0	1	1	1	1	100
150-159	4	1	1	0	5	1	20
160-169	2	0	4	1	6	1	17
170-179	2	0	3	0	5	0	0
180-189	4	1	1	0	5	1	20
190-199	3	1	3	2	6	3	50
200-209	6	1	8	8	14	9	64
210-219	3	0	21	5	24	5	21
220-229	7	3	13	4	20	7	35
230-239	7	0	14	3	21	3	14
240-249	10	6	9	1	19	7	37
250-259	15	3	3	3	18	6	33
260-269	8	7	1	1	9	8	89
270-279	3	2			3	2	67
280-289	9	2			9	2	22
290-299	1	1			1	1	100
300-310	1	0			1	0	0
	85	28	82	29	167	57	

Cubs and juveniles,
average infection 33%Subadults and adults,
average infection 36%

and trappers abandoned polar bear carcasses after they had skinned the animals. These carcasses must have been an important food supply for arctic fox during the winter, when other food was scarce. The foxes from northwest Spitsbergen were collected after six years of total polar bear protection. Polar bear carcasses were consequently not available as fox food. Foxes in this region mainly depend upon dead reindeer (*Rangifer tarandus platyrhynchus*), ringed seal pups, birds, or caches collected during summer. A low infection rate in Svalbard foxes is probably natural.

The occurrence of *Trichinella* in the Arctic is far more common in polar bears than in any other free-roaming species. But the high infection rates cannot be explained by their consumption of seals, nor occasional preying upon walrus or other species. Polar bears have a large muscle mass and high longevity. Scavenging and possibly also cannibalism (Taylor *et al.* 1983) are normal in this species. The interaction of these factors causes the polar bear to act as an infection reservoir for trichinellosis, and maintains the circulation of the parasite in the ecosystem of which the polar bear is a part. In areas where polar bear hunting is permitted, carcasses left in the field

after being skinned will maintain trichinellosis in polar bears in that region.

In this study, the infection rate in Svalbard bears varies between 58% found in the material from Bjørnøya around 1950, and 23 to 33% in the samples collected between 1966 and 1970 (Table 1). Material from the 1950s studied by Thorshaug & Rosted (1956) showed 59% infection in 278 samples from Svalbard and Greenland polar bears. Chi-square tests show significant differences between that study and infection in Svalbard samples after 1966 ($P < 0.001$). When polar bears were protected from hunting in the Soviet Union in 1956, the annual harvest in the western Soviet arctic and adjacent waters was reduced by more than 100 bears (Uspensky 1969). This means that relatively fewer bear carcasses were left in the field available for scavenging. This would in turn have reduced the probability of *Trichinella* infection in live bears from Svalbard and the western Soviet arctic which belong to one common population (Larsen 1978; Larsen *et al.* 1980), and may explain the difference between the material from the 1950s and later years.

Significant differences in percentage trichinellosis between polar bears of different sizes, i.e. age, could not be demonstrated in this study. Nor

could we find that the number of *Trichinella* larvae per g muscle tissue increased with age. Some bears are infected before they are weaned and become mature, but many adult bears remain uninfected (Table 3, Fig. 1). Some reservations must be made because of the small sample size, but when samples are pooled in a cub/juvenile and a subadult/adult group, there is still no difference between them. Because polar bears are typical scavengers and sometimes cannibals, one would expect that the longer a bear lives, the greater the probability of an infection. One possible explanation is that infected bears die, so that the relative infection rate remains stable with increasing age. But this would mean that adult bears would be absent from the population, which they are not (T. Larsen, unpublished data). Such a mechanism would also be a significant mortality factor. Because polar bears have a low recruitment rate and very slow population growth (Taylor 1982), deaths from trichinellosis would be detrimental to the population.

Previous studies have shown that trichinellosis in polar bears where 100 or more animals have been studied, varies between 24 and 64% (Roth 1949; Thorshaug & Rosted 1956; Fay 1960; Madsen 1961; Lentfer 1976). The low infection rate in Svalbard bears between 1966 and 1970 is comparable with the 24 to 26% infection rate found in Greenland bears (Roth 1950; Madsen 1961). Chi-square tests could not reveal significant differences ($P < 0.05$). Recoveries of bears marked in Svalbard show that some of them migrate to east Greenland (Larsen 1972). Craniometric studies have revealed differences between bears from many regions, but not between Svalbard and east Greenland bears (Manning 1971). There is probably an exchange of bears between the two areas, which in turn may explain the similarity in *Trichinella* infection rates. Mark/recapture programmes have demonstrated that there are several discrete subpopulations off the North American coasts, with limited exchange between them (Lentfer 1972; Stirling *et al.* 1977, 1980; Stirling & Kiliaan 1980). Chi-square tests show significant differences ($P < 0.001$) in samples of more than 100 specimens between Alaska and Canada and between Alaska/Canada and Greenland. The differences cannot be found in biases caused by methods used, because all studies referred to used the compression method. Furthermore, the differences are probably not caused by sex and age differences in the material, because

trichinellosis in polar bears seems to be independent of sex and relatively independent of age, according to our study. The polar bear hunt in Svalbard, Greenland and Canada, and partly in Alaska before 1960, was not selective with regard to sex and age, which would have minimized a sampling bias if it had been. We may therefore observe differences in *Trichinella* infection rates which reflect polar bear population discreteness.

Polar bears may have developed an active resistance which reduces their risk of being heavily infected with *Trichinellas* from arctic ecosystems. During the winter 1950–51, Odd Lønø fed four sledge dogs with polar bear meat which was positively infected. A later autopsy of the dogs showed that only one of them had been infected from the polar bear meat (Thorshaug & Rosted 1956). Laboratory mice and man react differently to arctic strains of *Trichinella* and infections from southern regions. Nelson *et al.* (1966) and Dunn (1978) found that *Trichinella* from Alaska had a lower infectivity in rats and domestic pigs than the European strain of the same parasite. *Trichinella* from wild polar bears from Frans Josef Land and Wrangel Island had less infectivity in laboratory mice than laboratory *Trichinella* strains and strains from southern regions (Ozeretskoykaya *et al.* 1969; Pereverzeva *et al.* 1973). It has been demonstrated that polar bears are more vulnerable to *Trichinellas* from southern regions than they appear to be to strains from their natural environment. Between 1946 and 1964, nine polar bears in Moscow Zoo died from trichinellosis after they had been infected by pest rodents (Khutoyanskii & Nemov 1969). Autopsy of an adult female polar bear which was born in captivity and died in Como Zoo in Minneapolis, showed a mass infection of *Trichinella* which it must have received from eating infected meat or pest animals in the zoo (M. Taylor, pers. comm.). Ozeretskoykaya *et al.* (1969) showed that humans infected with *Trichinella* on the arctic Bennett Island showed symptoms after an average 30.5 days, while persons who received trichinellosis in the Bryansk and Smolensk provinces on the Russian mainland, showed symptoms after an average 21.3 and 21.2 days, respectively. The findings above show that *Trichinella* strains which occur in the Arctic differ from others with regard to infectivity and other properties. Nelson (1970), Pawlowski (1981), and Steele & Schultz (1978) state that many areas of the world have their own peculiar *Trichinella* strains that behave differently

in their natural foci, and that such strains have different infectivity. Recent research has shown that there are at least three different strains of *Trichinellas* in natural ecosystems. The taxonomic classification is still controversial (Martinez Fernandez & Duran 1981; Pawlowski 1981). All three strains are morphologically identical, but have different biological characteristics and do not interbreed (Britov & Boev 1972; Dunn 1978). In this study, we have classified them as species with the nomenclature *Trichinella spiralis*, *Trichinella nativa*, and *Trichinella nelsoni*, according to R. Vik (pers. comm.). Modern research classifies *Trichinella nativa* as the aboriginal species which had wild Asian carnivores as its hosts (Britov & Boev 1972; Dunn 1978). *Trichinella spiralis* is a younger species and originated from *Trichinella nativa* when the pig was domesticated in Asia 5000–8000 years ago (Dunn 1978). From Asia it was transported to Europe and much later to North America, where trichinellosis until then had been absent. Many studies assume that trichinellosis in the Arctic is caused by *Trichinella spiralis*, but do not give any further classification (Roth 1949; Rausch *et al.* 1956; Madsen 1961; Thing *et al.* 1976; Born *et al.* 1982). Ozeretskovskaya & Uspensky (1957) and Dick & Chadee (1981) suggest that *Trichinella* in arctic Soviet Union and in Canada are *Trichinella nativa*. In our opinion, *Trichinella nativa* can have entered arctic ecosystems from Asia long before humans settled in the Arctic. Early explorers and other human activities in the last few hundred years may have introduced other *Trichinella* strains to the Arctic. Thus, different *Trichinella* strains or sibling species may be present in different arctic regions.

We can therefore offer three possible explanations for the significant differences in *Trichinella* infections found in polar bears from various areas:

1. The almost exclusive circulation of *Trichinella* in polar bears within geographically isolated areas may encourage parasite/host co-evolution and a greater tolerance by the host towards the parasite, as described by Ozeretskovskaya *et al.* (1969) and Dunn (1979). This may explain the polar bear tolerance against infections, and may also explain differences in infectivity between bear populations because of differences in evolutionary patterns.

2. Subpopulations of polar bears may have been or may be exposed to different strains of *Trichi-*

nellas with different infectivities. This may explain the differences in infection rates between populations.

3. Differences in polar bear hunting practices and harvest levels may cause differences in the likelihood of live bears being infected through scavenging, which again may explain differences in infection rates between populations.

We do not know which of these mechanisms, or whether a combination of them, regulate trichinellosis in polar bears. However, the significant differences in *Trichinella* infection rates between areas confirm the lack of mass exchange of bears previously demonstrated through marking and recapture programmes, satellite telemetry and morphometric studies. If polar bear populations were not relatively discrete, migration and exchange of bears would cause more uniformity in infection rates throughout the Arctic. Quantification of *Trichinella* rates in polar bears may therefore be another tool with which to discriminate between populations. It should only be used, however, when samples are representative and sufficiently large, when preservation and laboratory techniques are comparable, and if sampling is done simultaneously. Further studies need to be done on *Trichinella* taxonomy in the Arctic, and on the infectivity and biological properties of strains or sibling species occurring in polar bears.

Acknowledgements. - We thank the following persons and institutions for making this study possible: Muscle samples for *Trichinella* analyses were collected by Ian Gjertz, Per Johnson, Christian Lydersen, Odd Lønø, Pål Prestrud, Arild Strand, Kristian Torsvik, Svein Ytreland, and by weather station crew on Hopen 1966–67 and 1969–70. The material from Bjørnøya was made available to us by the Zoological Museum in Oslo. Lillian Meling and Sverre Trosvik helped with the laboratory work, and Halldis Lie, Dr. Ian Stirling, Dr. Mitchell Taylor and Dr. R. Vik offered valuable help and criticism during the writing of the manuscript. The work was financed by Norsk Polarinstitutt.

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