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# Arctic Rabies – A Review

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**Mørk T, Prestrud P: Arctic rabies – a review. Acta vet. scand. 2004, 45, 1-9.** – Rabies seems to persist throughout most arctic regions, and the northern parts of Norway, Sweden and Finland, is the only part of the Arctic where rabies has not been diagnosed in recent time. The arctic fox is the main host, and the same arctic virus variant seems to infect the arctic fox throughout the range of this species. The epidemiology of rabies seems to have certain common characteristics in arctic regions, but main questions such as the maintenance and spread of the disease remains largely unknown. The virus has spread and initiated new epidemics also in other species such as the red fox and the racoon dog. Large land areas and cold climate complicate the control of the disease, but experimental oral vaccination of arctic foxes has been successful. This article summarises the current knowledge and the typical characteristics of arctic rabies including its distribution and epidemiology.

***Arctic fox rabies; epidemiology, review.***

## Introduction

The history of rabies in the Arctic before 1945 is sparsely known. The folklore of the Canadian inuits indicates that these people knew of a rabies-like disease that was transmitted from arctic foxes to dogs and people (*Singleton* 1969), and in Greenland epidemics among sledge dogs have been described for almost 150 years (*Lassen* 1962). Rabies virus was first identified in arctic regions by *Williams* (1949). Epidemics among sledge dogs, initiated by transmission from rabies-infected arctic foxes, have caused severe problems in several arctic areas, sometimes reducing the number of sledge dogs drastically (*Sikes* 1968, *Holck* 1989, *Crandell* 1991). After the onset of dog vaccination, rabies has remained mainly as a disease of the arctic fox in these regions. There are several examples of southward spread of rabies virus from arctic regions (*Tabel et al.* 1974, *Webster et al.* 1986, *Johnston & Fong* 1992, *Selimov et al.* 1990) and arctic rabies represents a permanent potential source of infection of sub-arctic areas (*Anonymous* 1990).

## The arctic virus variant

Rabies virus belongs to the family *Rhabdoviridae* and the genus Lyssavirus. The genotype 1 consists of the classic rabies virus, while the other known genotypes consist mainly of viruses circulating among fruit and insect eating bats. By monoclonal antibody technique and genome analysis, different antigenic variants circulating in different main hosts within certain geographical areas have been identified (*Webster et al*. 1986, *Nadin-Davis* 1998, *Bourhy et al.* 1999). This supports the theory that rabies virus adapts to different main hosts for persistence in the host population (*Wandeler et al.* 1994).

Characterisation with monoclonal antibodies has indicated that a specific virus variant reacting with the monoclonal antibody (Mab) P-41, circulates in arctic areas (*Schneider et al.* 1985), and the arctic fox is regarded as the main host of this virus variant (*Johnston & Fong* 1992). The arctic strain has also been isolated from other animal species, such as red fox (*Vulpes vulpes*), racoon dog (*Nyctereutes procyonoides*) and skunk (*Mephitis mephitis*) in sub-arctic areas (*Webster et al.* 1986, *Westerling* 1989, *Selimov et al.* 1990, *Nyberg et al.* 1992). However, there are examples of virus isolates from far more southern areas, not likely to be the arctic strain, which have reacted positively with Mab P-41, indicating that a more complete monoclonal antibody panel is necessary for identification of the arctic strain (*Selimov et al.* 1994). The reverse transcriptase-polymerase chain reaction (RT-PCR) methodology has facilitated genetic characterisation of rabies virus isolates and has been used both as a diagnostic and as a characterisation tool to identify different strains persisting in certain host species within geographically defined regions. In Canada, 5 different variants of the arctic strain, obtained from different geographical areas, have been identified by RT-PCR (*Nadin-Davis* 1998).

**Distribution**

Rabies virus is endemic throughout most parts of the Arctic, and several epidemics have been reported during the last 40-50 years (*Raush* 1958, *Kantorovich* 1964, *Crandell* 1975, *Ritter* 1981, *Holck* 1989). In Alaska, rabies-like disease was first reported in 1887 and rabies virus was identified during an epidemic in 1945-47 (*Williams* 1949). Today, rabies is regarded as endemic among the red fox and the arctic fox in northern and western areas of Alaska, with a cyclic occurrence of epidemics about every 3-4 years (*Ritter* 1981, *Follmann* 1990).

In arctic Canada, rabies-like disease was reported from the North West Territory already in 1867 and the relationship between this disease in arctic foxes and similar epidemics among sledge dogs was noted in 1916 (*Elton* 1931). Today, the arctic strain virus persists among arctic foxes in the north and until recently caused several epidemics among red foxes and skunks in Ontario and Qubeck in the southeast (*Webster et al.* 1986, *MacInnes et al.* 2001).

In Greenland, epidemics of rabies-like disease among sledge dogs were reported as far back as 1859, but the virus was first identified among dogs and arctic foxes in 1959. There have been several large epidemics among sledge dogs in Greenland prior to 1960, when vaccination of dogs was initiated (*Holck* 1989, *Lassen* 1962). Rabies virus is still considered as endemic among the arctic fox population.

In Arctic Russia, rabies virus was first identified during a major research study from 1954 to 1956 in the Nenets Autonomous Okrug in northwest of Russia. The study confirmed that the rabies-like disease known from arctic foxes and dogs in arctic regions of Russia, was caused by rabies virus (*Kantorovich* 1964). The arctic virus strain has later been found in several arctic regions of Russia and also in several different animal species south of the arctic region (*Selimov et al.* 1990, 1994). From the Kola Peninsula, which borders Finland and Norway, arctic rabies was reported in the late 1980s (*Westerling* 1989, *Selimov* 1990).

In the high-arctic Svalbard islands of Norway, rabies was detected for the first time in 1980 when there was an outbreak in the arctic fox population. Rabies was also diagnosed in 3 reindeers and 1 seal (*Ødegaard & Krogsrud* 1981). Only few cases were reported from 1980-1992 and during the last years there have been speculations whether the rabies virus had died out naturally. However, in an ongoing research project, rabies was diagnosed recently in one fox from 1998 and one from 1999 (*Mørk & Fuglei, unpublished data*).

The mainlands of Norway and Sweden have

both been regarded as rabies free countries during the last 150 years. Reports of rabies in Sweden date back to 1886 (*Wierup & Engvall* 1990), while there are no reports of rabies in the mainland of Norway.

Finland was declared free of rabies in 1936. Since then there have been several epidemics, all close to the Russian border. In 1988 there was an outbreak in southern Finland, and the main species involved was the racoon dog, a species established in Finland about 1970-80. The epidemic was caused by the arctic virus strain and was successfully stopped by bait vaccination (*Westerling* 1989, *Nyberg et al.* 1992). Except for one imported case in a horse in 2003, no cases of rabies have been reported from Finland since 1989.

**Clinical appearance**

The incubation period in experimentally infected arctic foxes has been reported to vary from 8 days to 6 months (*Konovalov et al.* 1965, *Rausch* 1972). The clinical course is usually short and foxes may die within a day or 2 after the onset of symptoms. Initially, the arctic fox looses its natural timidity. It may enter villages or human settlements and there are examples of foxes having followed dog teams. In the exitative phase, the fox becomes aggressive and may snap and bite, and sometimes runs in circles. Excessive drivelling and foaming are also typical symptoms. In the following phase, the animal becomes paralytic and eventually dies. Both the furious form of the disease, dominated by aggressive behaviour, and the dumb non-aggressive form, dominated by paralysis, have been described in the arctic fox (*Kantorovich* 1964, *Crandell* 1991).

Rabies has previously been regarded as 100% lethal. However, the ecology of rabies has been shown to be more complex. Among spotted hyenas in Serengeti of East-Africa, a rabies seroprevalence of 37% was found, and rabies RNA was demonstrated among 13% of the hyena population. Despite this high frequency of exposure, there were no cases of symptomatic rabies or decreased survival among a group of hyenas monitored for 9 to 13 years (*East et al.* 2001). There are reports of experimental rabies cases, where dogs have recovered from the disease and have been secreting virus in the saliva for a longer period after recovery (*Fekadu et al.* 1981, *Fekadu* 1983). Apparently healthy dogs have been found to secret rabies virus in their saliva during a period, and remained clinically normal during several years after the first virus isolation (*Nanavati* 1973, *Fekadu* 1975). Serological surveys of wild animal populations have been limited, but rabies antibodies have also been found in arctic foxes in Alaska, indicating that some foxes survive virus exposure (*Ballard et al*. 2001).

**Zoonotic aspects**

There have been few human cases of rabies in the arctic regions, and it has therefore been claimed that the arctic virus strain is less pathogenic to man (*Johnston & Fong* 1992). However, there might be other explanations. An important aspect is that people rarely become infected from foxes, thus the most probable exposure is through dogs. There are several reports indicating that most dogs infected with arctic rabies develop "dumb rabies", which reduces the risk of human infection (*Kantorovich* 1964, *Holck* 1989). The fact that the Arctic is scarcely populated and that people wear protective outdoor garments in the cold climate, might be of some importance, as well as lack of rabies diagnostics facilities (*Kuzmin* 1999). In Greenland, only one single human case of rabies has been reported. During the epidemic of Egesminde in 1960, a four- year- old girl was bitten in the face by a dog and died from rabies 3 months later (*Lassen* 1962). From arctic Russia, there are reports of several human cases. A man is reported to have developed rabies after being bitten in the nose by an arctic fox in 1982, in Anadir, Chukot of northeast Siberia (*Selimov et al.* 1990). Three human cases in 1987-98 in the Pskov and Leningrad districts, were assumed to be caused by the arctic strain, based on known occurrence of the virus in wildlife population (*Selimov et al*. 1994). In 1998, a man died of rabies in Norilsk in northwest of Siberia after being bitten by a rabid wolf. The man was given rabies vaccine but rabies immune globulin was not available and the man developed clinical rabies. Virus isolation and typing (mab) identified the virus as the arctic strain (*Kuzmin* 1999).

Naturally acquired immunity to rabies among inuit populations due to non-bite exposure from handling foxes, wolfs and caribous has also been suggested as a possible explanation to the low number of human cases in the Arctic. In Alaska, one experienced arctic fox trapper was found to have a rabies serum neutralising antibody concentration as high as 2.30 IU/ml. The man had never received pre- or postexposure rabies vaccination (*Follmann et al.* 1994). Low level antibody titers have been demonstrated among Canadian inuits (0,05-0,09 IU/ml), however, it is uncertain wether the results from this study really represent antibodies againts rabies virus or wether they were caused by a cross-reacting antigen (*Orr et al.* 1988).

**Epidemiology**

The contact rate, which describes how many animals that will become infected on average by one infected animal, varies and depends on the social organisation, the population density and ecology of the animal species (*MacDonald & Voigt* 1985). When a population density is high and/or the animals migrate, the contact rate will increase, and it is postulated that there is a positive correlation between the prevalence of rabies and the population density. What causes the start of an epidemic and how rabies is maintained in different animal populations, is largely unknown. The density among red foxes in Ontario, Canada, where arctic rabies was endemic until a successful campaign of bait vaccination, is lower than what is regarded as necessary to maintain the disease among red foxes in Central Europe (*Voigt & Tinline* 1982). Different virus variants with different characteristics may be a possible explanation to such geographical differences.

The ecology of the arctic fox makes it a suitable host for the rabies virus. Wild rodents such as lemmings are the most important source of food for the arctic fox throughout the Arctic, except on some islands where wild rodent populations are absent. The relationship between the well known 3-5 year cycles in wild rodent population density and the variation in numbers of arctic foxes, is well documented from most parts of the Arctic (*Ängerbjörn et al.* 1995, 1999) and, as mentioned above, several authors have made the hypothesis that there is a connection between high population densities of arctic foxes and outbreaks of rabies (*Elton* 1931, *Kantorovich* 1964, *Syuzyumova* 1968, *Ritter* 1981). The number of litters being born may vary as much as from 5 to 25 pr 100 $km^2$ as a result of increased food availability, and the litter size may increase 2 or 3 times (*Angerbjörn et al.* 1999). As a result, variations in fox densities may be 10-fold between a peak and a bottom of the rodent density cycles.

Even at the highest peaks in numbers of reproducing arctic foxes, the population density is still low compared to the density of reproducing red foxes in Europe. In the higharctic Svalbard archipelago, rodents are present only in a small, defined area and foxes pray mainly on birds and carcasses of reindeer and seal. The arctic fox population is fairly stable and significantly smaller in this area than in most other parts of the Arctic. A rabies outbreak occurred in 1980, and rabies virus seems to still persist in the arctic fox population. However, there were no indications of a peak in the fox population on the island during 1980-1992 (*Prestrud* 1992).

Some of the epidemics described from the Arctic have a similar course, which seem to differ from what is seen in other areas of the world. Extensive outbreaks, where a major part of the arctic fox population is infected, seem to last for a year or 2, followed by a period of 6-10 years where cases are decreasing, before a new epidemic emerges. There seems to be a cyclic variation through the year, with most cases in late winter and early spring (*Kantorovich* 1964, *Syuzyumova* 1968, *Crandell* 1975). This may be explained by a plausible increase in the contact rate caused by onset of the mating season when foxes actively defend their territories against intruders. However, arctic fox populations most commonly peak during autumn when the litters leave their dens. Autumn is also a period when foxes disperse and migrate and one should assume that the contact rate would be high at this time of year. If an outbreak starts in autumn, the virus may spread in the population due to high density of foxes, and number of cases will increase throughout the winter (*Raush* 1972). When mating starts in late winter, the contact rate might increase further and may lead to a peak in the outbreak.

There have been several studies measuring the prevalence of rabies among trapped arctic foxes, in both the epidemic and the endemic periods (*Reviewed by Prestrud et al.* 1992). It is apparent that the prevalence varies to a great extent, and that up to 75% of the population may be infected during an epidemic. Also between epidemics, rabies virus has been demonstrated in some animals (0,7%-3%). Some authors have made the conclusion that positive diagnosis of rabies among presumably healthy foxes indicates that the arctic fox might carry the rabies virus for prolonged periods of time without showing clinical signs of infection. (*Kantorovich* 1964). Others believe that the animals have been in the prodromal phase at the time of capture (*Secord et al.* 1980). Animals less than one year of age seem to dominate in these studies and several authors have concluded that rabies predominately affects young individuals (*Kantorovich* 1964, *Secord et al.* 1980, *Ballard et al*. 2001).

How rabies virus is maintained in arctic fox population through periods with low population densities remains unknown. Long incubation periods, prolonged periods of virus excretion and oral infection through frozen carcasses where the virus may be preserved for longer periods of time, are mentioned by several authors as possible explanations (*Tabel et al.* 1974, *Cherkasskiy* 1990). Peroral infection in red foxes has been reported (*Ramsden & Johnston* 1975), and this could be a possible route of transmission for arctic foxes as well.

There are examples of experimental infection of arctic foxes, where a few individuals have not developed clinical disease, nor seroconverted, which may suggest that these animals were less susceptible to the virus or that the incubation period was particularly long and that the animals where euthanised before development of clinical disease (*Follmann pers. comm.*).

Long time absence of the disease in a population, may be explained by a situation where the virus is no longer circulating in the population, and that new epidemics is caused by re-introduction of the virus. The arctic fox is known to be among the mammals with the longest migrations (*Eberhardt & Hanson* 1978) and it is not unusual to see arctic foxes out in the drift ice, where they prey on seal carcasses left by the polar bear.

Other animal species in the Arctic seem to be infected by rabies more sporadically. In Svalbard, there have been several cases reported among the Svalbard reindeer (*Rangifer taran-*

*dus plathyrynchus*) (*Ødegaard & Krogsrud* 1981), and also from Russia there are reported cases among reindeer (*Anonymous* 2000). Rabies in seals is probably rare. In addition to one confirmed case of rabies in a ringed seal (*Phoca hispida*) on Svalbard (*Ødegaard & Krogsrud* 1981), there is only one report of a seropositive grey seal (*Halichoerus grypus*) on the Estonian island Ösel (*Westerling & Stenmann* 1992). Bears are considered as less susceptible to rabies, and only one single case of rabies in a polar bear (*Ursus maritimus*) has been reported in Canada. (*Taylor et al.* 1991).

The wolf (*Canis lupus*) seems to be of more importance. Both in Russia and in Alaska there are examples of wolves infecting humans. Rabies epidemics are known from certain wolf populations in Alaska, which seem to coincide with epidemics in the arctic fox population (*Weiler et al.* 1995). In periods with large wolf populations, this species has had an important role in rabies epidemics both in northern and southern parts of Russia. Populations of wolf-dog-hybrids have also been known from several areas of Russia. Furious wolves and wolf-dog-hybrids are extremely dangerous to man, because of a tendency to bite in the head, and the bites are often multiple and deep (*Cherkasskiy* 1988).

The red fox, as well as the racoon dog, may be involved in arctic rabies epidemics (*Webster et al.* 1986, *Nyberg et al.* 1992). The racoon dog is quite common in Russia and has been established in the south and middle parts of Finland and the Baltic states. It has also been observed in Sweden and in Norway.

**Control**

Rabies control by bait vaccination of wild animals has shown to be successful in several areas, such as Central-Europe, Finland and Canada (*Nyberg et al.* 1992, *Müller* 2000, *MacInnes et al.* 2001). Experimental oral vaccination of captured arctic foxes in Alaska has shown to be effective (*Follmann et al.* 1988, 1992) and limited trials on bait vaccination has shown that there is a potential for field vaccination of arctic foxes (*Anonymous* 1990). However, the existing vaccines have little effect in frozen condition, which is a limiting factor in arctic regions. The vaccine is distributed inside a capsule, which is punctured when the animal eats the bait. The vaccine will then be released in the oral cavity and absorbed through buccal mucosae. In frozen condition the vaccine will first thaw in the stomach, where previous experimental work has shown absorption to be limited and subsequent immune response to be rare (*Anonymous* 1990). The amount of infective virus in the bait will also be reduced or eliminated after repeatedly freezing and thawing. Knowledge of the etiology and ecology of the animal species in question and the relative number of animals being vaccinated, is vital to succeed with bait vaccination.

**Concluding remarks**

The arctic fox rabies virus seems to persist in most arctic areas. Exposure rates to humans and domestic animals are in general relatively low. However, risk of exposure might be high during periods of larger outbreaks or in certain areas. Clearly, problems are connected to control of rabies in arctic areas, mainly due to the size of land areas and lack of infrastructure. The most realistic aim in controlling rabies would probably be to stop spread of the disease to rabies-free areas and to eliminate the disease or reduce cases in limited areas.

Many questions concerning the epidemiology of arctic rabies remain unsolved and these questions are most likely closely related to the characteristics of the arctic virus strain and the ecology of the arctic fox.

## References


*Angerbjörn A, Tannerfeldt M, Bjärvall A, Ericson M, From J, Noren E:* Dynamics of the arctic fox population in Sweden. Ann. Zool. Fenn. 1995, *32,* 55-68.

*Angerbjörn A, Tannerfeldt M, Erlinge S:* Predator-prey relationships: Arctic foxes and lemmings. J. Anim. Ecol. 1999, *68,* 34-49.

*Anonymous:* Rabies Bulletin Europe, http://www.who-rabies-bulletin.org/, 29.11.2000.

*Anonymous:* World Health Organization. Report of a WHO/NVI workshop on arctic rabies, WHO/Rab. Res./90.35. Uppsala, Sweden 1990.

*Ballard WB, Follmann EH, Ritter DG, Robards MD, Cronin MA:* Rabies and canine distemper in an artic fox population in Alaska. J. Wildl. Dis. 2001, *37,* 133-37.

*Bourhy H, Kissi B, Audry L, Smreczak M, Sadkowska-Todys M, Kulonen K, Tordo N, Zmudzinski JF, Holmes EC:* Ecology and evolution of rabies virus in Europe. J. Gen. Virol. 1999, *80,* 2545-57.

*Cherkasskiy BL:* Roles of the wolf and the raccon dog in the ecology and epidemiology of rabies in the USSR. Rev. Inf. Dis. 1988, *10,* 634-36.

*Cherkasskiy BL:* The epidemiological surveillance on Arctic fox rabies. WHO/NVI Workshop on arctic fox rabies, Uppsala, Sweden. Background papers, 1990, 25-28.

*Crandell RA:* Arctic fox rabies. In: The Natural History of rabies, vol. II, Baer GM (ed.) Academic Press Inc, New York, 1975, 23-40.

*Crandell RA:* Arctic fox rabies. In: The Natural History of Rabies, second edition, Baer GM (ed), CRC Press, New York 1991, 291-306.

*East ML, Hofer H, Cox JH, Wulle U, Wiik H, Pitra C:* Regular exposure to rabies virus and lack of symptomatic disease in Serengeti spotted hyenas. PNAS, 2001, *98* (26), 15026-31.

*Eberhardt LE, Hanson WC:* Long-distance movements of arctic foxes tagged in northern Alaska. Can. Field-Nat. 1978, *92,* 386-89.

*Elton C:* Epidemics among sledge dogs in the Canadian Arctic and their relation to disease in the arctic fox. Can. J. Res. 1931, 58, 673-92.

*Fekadu M:* Asymptomatic non-fatal Canine Rabies. Lancet 1975, *1,* 569.

*Fekadu M, Shaddock JH, Baer GM:* Intermittent excretion of rabies virus in the salvia of a dog two and six months after it had recovered from experimental rabies. Am. J. Trop. Med. Hyg. 1981, *30,* 1113-5.

*Fekadu M:* Rabies virus in the tonsils of a carrier dog. Arch. Virol. 1983, *78,* 37-47.

*Follmann EH, Ritter DG, Baer GM:* Immunization of arctic foxes (*Alopex lagopus*) with oral rabies vaccine. J. Wildl. Dis. 1988, *24,* 477-83.

*Follmann EH:* Arctic fox rabies and oral vaccination experiments in Alaska. WHO/NVI Workshop on arctic rabies, Uppsala, Sweden. Background papers, 1990, 1-11

*Follmann EH, Ritter DG, Baer GM:* Oral vaccination of arctic foxes (*Alopex lagopus*) with an attenuated vaccine. Vaccine 1992, *10,* 305-08.

*Follmann EH, Ritter DG, Beller M:* Survey of fox trappers in northern Alaska for rabies antibody. Epidemiol. Infect. 1994, *113,* 137-41.

*Holck SN:* Rabiesforekomst i Grønland før og nu. (Occurrence of rabies in Greenland, before and now). Dan. Vet. Tidsskr. 1989, *72,* 22-30.

*Johnston DH, Fong DW:* Epidemiology of Artic fox rabies. Wildlife rabies control. Proceedings of the international WHO symposium on Wildlife Rabies Control, Geneva, 1990 and report of the WHO Seminar on Wildlife Rabies Control, Geneva 1990. Wells Wells Medical cop. 1992, 45-49.

*Kantorovich RA:* Natural Foci of a Rabies-like Infection in the far North. J. Hyg. Epidemiol. Immunol. 1964, *8,* 100-10.

*Konovalov GV, Kantorovich RA, Buzinov IA, Riutova VP:* Experimental investigations into rage and rabies in polar foxes, natural hosts of the infection. II An experimental morphological study of rabies in polar foxes. Acta. Virol. 1965, *9,* 235-39.

*Kuzmin IV:* An arctic fox rabies virus strain as the cause of human rabies in Russian Siberia. Arch. Virol. 1999, *144,* 627-29.

*Lassen HCA:* Hundegalskap i Grønland. (Rabies in Greenland). Ugeskrift for læger 1962, *9,* 269-72.

*MacDonald DW, Voigt, DR:* The biological basis for rabies models. In: P.J Bacon ed. Population dynamics of rabies in wildlife. Academic Press Inc., London 1985, 71-108.

*MacInnes CD, Smith SM, Tinline RR, Ayers NR, Bachmann P, Ball DGA et al.:* Elimination of rabies from red foxes in eastern Ontario. J. Wildl. Dis. 2001, *37,* 119-32.

*Müller WW:* Rabies in Europe - Epidemiological cycles and the impact of oral vaccination of foxes. Rabies Bulletin Europe 2000, *24,* 8-12.

*Nadin-Davis SA:* Polymerase chain reaction protocols for rabies virus discrimination. J. Virol. Methods 1998, *75,* 1-8.

*Nanavati A:* Rabies: A review of current problems and trends. Indian J. Med. Sci. 1973, *27,* 649-55.

*Nyberg M, Kulonen K, Neuvonen E, Ek-Kommonen C, Nuorgam M, Westerling B:* An Epidemic of Sylvatic Rabies in Finland- Descriptive Epidemiology and Results of Oral Vaccination. Acta. Vet. Scand. 1992, *33,* 43-57.

*Orr PH, Rubin MR, Aoik FY:* Naturally acquired serum rabies neutralizing antibody in a Canadian inuit population. Arctic Med. Res. 1988, *47,* 699-700.

*Prestrud P:* Population Dynamics of Artic foxes, Alopex Lagopus, in Svalbard. In the Dr.philos thesis, Arctic foxes in Svalbard: Population ecology and rabies, 1992, Paper 6, 166-200.

*Prestrud P, Krogsrud, Gjertz J:* The occurence of rabies in the Svalbard islands of Norway. J. Wildl. Dis. 1992, *28,* 57-63.

*Ramsden RO, Johnston DH:* Studies on oral infectivity of rabies virus in carnivora. J. Wild. Dis. 1975, *11,* 318-24.

*Rausch R:* Some observation on rabies in Alaska, with special reference to wild canidae. J. Wildl. Manage. 1958, *22,* 246-60.

*Rausch RL:* Observation on some natural-focal zoonoses in Alaska. Arch. Environ. Health. 1972, *25,* 246-52.

*Ritter D:* Rabies. In: Dietrich RA ed. Alaskan wildlife diseases, University of Alaska, Fairbanks, Alaska 1981, 6-12.

*Schneider LG, Ødegaard ØA, Mueller J, Selimov M:* Application of monoclonal antibodies for epidemiological investigation and oral vaccination studies. II Arctic viruses In: Rabies in the Tropics. Ed. Kuwert E, Merieux C, Koprowski H and Bögel K., Springer -Verlag, Berlin, 1985, 47-59.

*Secord DC, Bradley JA, Eaton RD, Mitchell D:* Prevalence of rabies virus in foxes trapped in the Canadian Arctic. Can. Vet. J. 1980, *21,* 297-300.

*Selimov MA, Botvinkin AD, Khozinskii VV, Klyueva EV, King A, Petrenko LG, et al.:* Lyssavirus characterization with monoclonal antibodies on strains of certain regions of the USSR. Rabies Bulletin Europe 1990, *14,* 8-9.

*Selimov MA, Botvinkin AD, Khozinskii VV, Gribanova L:* New data on the spread of P-41 positive strains of the rabies virus in arctic and extra-arctic regions. J. Microbiol. Epidemiol. Immunol. USSR. 1994, 2, 53-56.

*Sikes RK:* Arctic rabies. Arch. Environ. Health. 1968, *17,* 622-26.

*Singleton, JR:* The history of rabies in Canada. Can. State Vet. J. 1969, *24,* 205-09.

*Syuzyumova LM:* Epizootiology of rabies among arctic foxes on the Yamal Peninsula. Problems of the North (Problemy Severa) 1968, *11,* 113-21.

*Tabel H, Corner AH, Webster WA, Casey CA:* History and epizootiology of rabies in Canada. Can. Vet. J., 1974, *15,* 271-81.

*Taylor M, Elkin B, Maier N, Bradley M:* Observation of a polar bear with rabies. J. Wildl. Dis. 1991, *27,* 337-39.

*Voigt DR, Tinline RR:* Fox rabies and trapping: a study of disease and fur harvest interaction. Proceeding of the Symposium 43rd Midwest Fish and Wildlife Conference, Wichita, Kansas 1982, 139-56.

*Wandeler AI, Nadin-Davis SA, Tinline RR, Ruprecht CE:* Rabies Epidemiology: Some Ecological and Evolutionary Perspectives. Curr. Top. Microbiol. Immunol. 1994, 297-324.

*Webster WA, Casey GA, Charlton KM:* Major antigenic groups of rabies virus in Canada determined by anti-nucleocapsid monoclonal antibodies. Comp. Immunol. Microbiol. Infect. Dis. 1986, *9,* 59-69.

*Weiler GJ, Garner GW, Ritter DG:* Occurrence of rabies in a wolf population in northeastern Alaska. J. Wildl. Dis. 1995, *31,* 79-82.

*Westerling B:* Rabiessläget i Finland. (The Rabies battle in Finland). Svensk Vet. Tidn. 1989, *41,* 315-17.

*Westerling B, Stenman O:* Hälsotilståndet hos säl i Östersjön. (The health condition of seals in the Baltic Sea). I veterinären och den yttre miljön, Nordisk komiteé för veterinärvitenskapeligt samarbete (7:e symposiet), Wik, Uppsala, Sverige 1992, 77-83.

*Wierup M, Engvall A:* Rabies - Sweden. WHO/NVI Workshop on arctic rabies, Uppsala, Sweden. Background papers 1990, 83-85.

*Williams RB:* Epizootic of rabies in interior Alaska. Can. J. Comp. Med. 1949, *13,* 136-43.

*Ødegaard ØA, Krogsrud J:* Rabies in Svalbard: Infection diagnosed in arctic fox, reindeer and seal. Vet. Rec. 1981, *109,* 141-42.

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**Sammendrag**

*Arktisk rabies - en oversikt*

Rabies synes å opprettholdes i de fleste arktiske regioner, og de nordlige deler av Norge, Sverige og Finland er de eneste områder av Arktis hvor rabies ikke har vært diagnostisert i nyere tid. Fjellreven er hovedvert og ser ut til å være infisert med den samme virusvarianten i hele sitt utbredelsesområde. Epidemiologien i arktiske områder synes å ha enkelte fellestrekk, men svar på essensielle spørsmål slik som opprettholdelse og spredning av sykdommen, er fortsatt ukjent. Spredning av viruset har forårsaket nye epidemier også hos andre arter som rødrev og mårhund. Store landområder og kaldt klima kompliserer kontroll av sykdommen, men eksperimentell oral vaksinasjon av fjellrev har vært vellykket. Artikkelen summerer opp typiske egenskaper ved arktisk rabies samt utbredelse og epidemiologi.


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