# REPORT OF A WHO/NVI WORKSHOP ON ARCTIC RABIES

*Uppsala, Sweden, 24-27 April 1990*

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1. INTRODUCTION

The outbreak of Arctic rabies which occurred in Finland in 1988 renewed the interest in Arctic rabies. This called for more research on epidemiology and control of Arctic rabies and strengthened international collaboration. The need for a better understanding of Arctic rabies and the development of specific control strategies should be seen in the light of the promising results already obtained in sub-Arctic areas especially in European countries where large-scale programmes for the elimination of red fox rabies are underway. Arctic rabies represents a permanent potential source of reinfestation of the areas which are expected to become free of wildlife, red-fox mediated, rabies in the near future.

The workshop was opened by Dr G. Hugoson, Director of the National Veterinary Institute (NVI). He welcomed the participants on behalf of the Swedish Government and assured them of the marked interest of the Minister of Agriculture in the outcome of their work. Dr P.-X. Meslin, welcomed the participants on behalf of the Director General of WHO and conveyed the wishes of Dr K. Bögel, Chief, Veterinary Public Health, for a successful meeting. He thanked Dr Hugoson, Director of the host institute and Dr B. Nordblom from the Board of Agriculture, for their assistance with preparations for the meeting.

Dr G. Hugoson was elected Chairman and Drs D. Gregory and D. Johnston accepted to be rapporteurs of the Workshop. The list of participants is attached as Annex 1.

2. NATIONAL REPORTS

2.1 USA (State of Alaska)

Rabies has probably been in Alaska for many thousands of years. However, the first actual identification of the rabies virus in Alaska did not occur until an epizootic in the mid-1940's in interior Alaska. Since that time, rabies has been principally restricted to the north and west coasts of Alaska, the last case in the interior having occurred in 1962. Rabies epizootics occur mainly during November through March in the Arctic fox but begin earlier in red foxes which are prevalent in southwest Alaska. In some years rabies has spread all over the north and west coasts, whereas in other years epizootics have been more localized.

The epizootics of rabies occur about every 3-4 years in Alaska and involve principally the Arctic fox (Alopex lagopus) and the red fox (Vulpes vulpes). In a sample of over 500 Arctic fox carcasses collected over a 5-year period following a major epizootic in northern Alaska, foxes under 1 year of age represented 66% of the sample. When determining, in the same collection of carcasses, the age classes between November and April, foxes under 1 year of age dominated the collection during November through January. Older animals did not dominate the collection until March and April. This suggests that young foxes are more susceptible to trapping, and perhaps move about more and earlier in the winter than older foxes. This could have important implications for a rabies control programme.

The State of Alaska began a rabies control programme in 1975 that involved immunizing domestic dogs and cats against rabies because the dog in particular was the usual route of exposure of people to the rabies virus. This programme reduced considerably the number of post-exposure prophylaxis cases and related costs.

In the mid-1980's a research programme was initiated to evaluate the effectiveness of the SAD-BKV21 oral rabies vaccine for immunization of Arctic foxes. The 6 vaccinated foxes had protective antibody titres (1:50) after 2 weeks but only 4 maintained their level after 6 weeks. The foxes received a vaccine booster at week 56 and all resisted a challenge made at week 62. The efficacy of the blood marker lophenoxic acid was also
determined for potential use in a bait programme. Foxes maintained marked levels of protein-bound iodine for up to 3 months. Future research involves testing the SAG vaccine on captive Arctic foxes.

Control of rabies in Arctic and Sub-Arctic Alaska will be very difficult because of: (1) the high mobility of foxes; (2) the general breakdown of territories in winter thus increasing the potential contact between foxes; (3) the seasonal occurrence of ice along the northern and western coasts which provide "bridges" for foxes to travel between land masses; (4) the cyclicity of the Arctic fox population; and (5) the large distances between sites of human habitations.

2.2 Canada

A history of rabies in Canada was given to provide an insight to the situation as it exists today. Four main rabies cycles exist in wildlife, which spill over into domestic animals and are responsible for 80% of the rabies cases reported annually. These four cycles are: (a) bat rabies which is found in all provinces, but in British Columbia and the Atlantic region, bats are the sole rabies hosts. In 1989, a bat rabies strain was isolated from two red foxes and a cow in the Atlantic region; (b) rabies in skunks which is found in all provinces with the exception of British Columbia and the Atlantic region. In the prairie Provinces of Manitoba, Alberta and Saskatchewan, the virus found in skunks is antigenically similar to that found in skunks from the Mid-western United States but dissimilar to that virus type found in Ontario and Quebec; (c) rabies circulating in Ontario and Quebec has its origin in the epidemic which moved down from the Arctic region starting in 1947. The main wildlife host species are the red fox and the skunk in Ontario which are responsible for 90% of the annual Canadian rabies cases; (d) Arctic fox rabies which has circulated in the North West Territories since at least 1950. The virus is antigenically identical to that found in wildlife in Ontario. It is not known if the virus has moved into Ontario on any other occasion since 1950 but it is almost certain to have been responsible for the 1988 outbreak in the Atlantic Region. This outbreak spread down the coast of Labrador and was the origin of a further outbreak in northern Newfoundland (an island which had last seen rabies in 1955). This latter outbreak was controlled in late 1988.

All rabies diagnoses are carried out in two federal laboratories, one in Lethbridge, Alberta and the other in Ottawa, Ontario.

In Ontario during 1989, 15,750 km² were baited with SAD-ERA vaccine. The wax-tallow, chicken-flavoured baits contained tetracycline hydrochloride as a biomarker. The baits were air-dropped at a density of 20 baits/km² by baiting machines installed in Twin Otter aircraft flying at a 150 meters elevation. The aircraft covered 1000 km²/day using Loran-C navigation to fly transect 1 km apart.

The area covered in 1989 represents 20% of the rabies-endemic area of Ontario. Baits were also distributed manually at ground level in 1989 in urban areas where air dropping was not feasible. Plans for 1990 are aimed at further automation and cost reduction for the coverage of large land masses.

During October 1988, 8,100 baits containing SAD-ERA vaccine were air-dropped in Labrador and Newfoundland in an initial trial to vaccinate Arctic foxes. Sera recovered from 3 Arctic foxes (tetracycline positive, FAT negative) gave ELISA antibody titres of 1/16, 256 and 1 024. This limited trial indicates there is potential for the field vaccination of Arctic foxes with SAD-ERA vaccine baits.
2.3 Finland

Finland was first declared free from rabies in 1936. However, during the years 1952 to 1959, two local epidemics occurred close to the national border. In all, 52 dogs, 2 cats and 1 red fox were found rabid. The disease was eradicated by vaccinating the local dog population against rabies and shooting stray dogs and cats. At that time the raccoon dog population was negligible.

In April 1988, a local outbreak of essentially sylvatic rabies occurred in the South-Eastern province of Kymi, about 100 km from the national border. The infection was possibly brought in by wolves migrating along the coast ices from the USSR. In all, 66 cases (48 raccoon dogs, 12 foxes, 2 badgers, 2 cats and 1 dairy bull) were confirmed by the laboratory between 8 April 1988 and 16 February 1989 on a 1700 km² large area.

At an early stage the local dog population was vaccinated at the state’s expense. During 1988, about 182,000 dogs, 63,000 cats and 27,000 other domestic animals were vaccinated in the whole country.

During 1988 and 1989, 3,025 animals of different species from the whole country were examined for rabies.

A field trial on oral immunization of raccoon dogs and foxes was started in collaboration with the European Centre for Rabies Surveillance and Research, WHO Collaborating Centre for Rabies Surveillance and Research, Tübingen, FRG.

2.4 Greenland

Rabies has been known to exist in Greenland for many decades especially among foxes and dogs. The first detailed description of an outbreak of “Eskimo dog disease” strongly evoking rabies was given in 1859. In 1959, rabies was for the first time confirmed in the laboratory. The State Veterinary Laboratory of Denmark has since accepted to examine all suspect samples originating from Greenland.

In 1960, in the Egedesminde district around 1,000 sledge dogs died of rabies. In this period vaccination of dogs against rabies was introduced. The result was that the number of dog rabies cases decreased drastically. From 1964 to 1975, a number of rabies cases were diagnosed in various animal species (Arctic foxes, sledge dogs, horses and sheep, caribous, especially in districts of the south-western coast (Disko Bay) and Thule district.

From 1975–1989 out of 350 suspect sledge dogs examined for rabies only 56 were positive, while 82 out of 120 Arctic foxes examined were found rabies positive. 3 other animals, 1 caribou and 2 cats from non-sledge dog districts in South Greenland, were all negative during the same period.

In 1987 Arctic foxes were found positive for rabies for the first time in Godthåb district. No other animals were affected. In 1988 rabies was only found in Arctic foxes from Thule, Upernavik, Sukkertoppen and Godthåb districts. The disease was not transmitted to dogs or other animals. In August 1989 a single sledge dog from Station Nord in the National Park of North and East Greenland was found rabid together with Arctic foxes from the same area.

Undoubtedly, the Arctic foxes are the natural reservoir of rabies in Greenland. Occasionally it is assumed that Arctic foxes from the Northwest Territories of Canada may migrate from the ice-covered strait from Ellesmere Island to Greenland. These circumstances perhaps explain why rabies among foxes in Greenland is diagnosed in the
Thule district and in some north western districts almost every year. So far, very little is known about the migration of Arctic foxes inside Greenland.

Since 1960 to date, only one case of human rabies has been reported. The Government Order of 1969 requires all dogs in Greenland to be vaccinated against rabies. Approximately, 28 000-30 000 sledge dogs in Greenland must constantly be kept immune against rabies. To this figure should be added non-sledge dog districts, estimated to represent around 1 000 dogs. Animals suspected of rabies must be destroyed and sent for laboratory rabies examination. When rabies occurs the affected districts or areas must be kept isolated for several months.

The results of present research programmes concerning oral wildlife rabies vaccination could probably lead to a practical way of rabies control in Greenland.

2.5 Norway (Svalbard Islands)

In the spring of 1980 rabies was diagnosed in 12 Arctic foxes, three reindeer and one ringed seal (Phoca hispida) in the Svalbard islands in the Arctic Ocean. These animals either showed abnormal behaviour or were found dead. This was the first confirmed outbreak of rabies in Svalbard. Investigations with monoclonal antibodies carried out in Tübingen gave evidence that the virus strains from Svalbard together with polar fox strains from other Arctic regions belong to an antigenic subgroup of Lyssavirus type 1. During the winter of 1980-81 two additional rabid foxes were found. In the spring of 1987, rabies was again diagnosed in two foxes and one reindeer, and in April 1990 in one fox. All the detected cases were located close to the settlements of Spitsbergen (the largest Svalbard island), except for one fox, which was found on an eastern island, approximately 300 km from the other cases.

During the years 1981-89, 491 trapped foxes were examined for rabies, all were negative.

There are no rodents which could represent an important food source for the fox in Svalbard. The fox lives mainly as a scavenger, eating carcasses of reindeer, seals and birds, but also takes live birds and eggs. Recent observations indicate that there is no large variation in the size of the fox population from year to year on the islands.

2.6 Poland

During 1948-69 most cases of rabies were reported among domestic animals, mostly dogs. The total number of rabid animals decreased from over 3 700 in 1948 to 65 cases in 1936. Since 1956 rabies is mostly diagnosed in wildlife, essentially in red foxes.

In 1989 a total of 1 891 animal rabies cases were diagnosed, the highest level since 1949. The disease was predominantly diagnosed in wildlife species, especially foxes. The following are rabies cases (% of total) for different species of animals; foxes - about 70%; farm animals - 9%; raccoon dogs - 7.9%; cats - 7.9%; and dogs - 4.4%.

Out of 49 provinces, only one was rabies free in 1989. Rabies in foxes was reported in 47 provinces; in cats in 36 provinces; in dogs in 28 provinces; and in raccoon dogs in 20 provinces.

The red fox is still considered to be the main host species maintaining the current epizootic of rabies in Poland. However, in some areas it should be noted that the number of cases in raccoon dogs outnumbered those diagnosed in foxes.
During the period 1985-1989, the percentage of rabies cases diagnosed in raccoon dogs increased from 3.5% to 7.9%. Data collected from two provinces (Olszty, Suwalki) where raccoons in raccoon dogs has been reported for over 35 years, show that in 1989 the cases of raccoons in these animals outnumbered those diagnosed in foxes in Olszty by 138.3% and Suwalki by 135.2%.

In conclusion, it can be stated that in Poland: (1) rabies is found predominantly in wildlife; (2) the red fox is responsible for maintaining the epizootic of raccoons in the country; (3) the raccoon dog has become the second wildlife species in which raccoons is diagnosed.

2.7 USSR

Two major types of raccoons are present in the USSR: wildlife raccoons in the western part of the country maintained in red foxes and urban raccoons in the eastern part maintained in free roaming dogs.

The raccoon dog was imported from the eastern part to the northwestern part of the country to increase the fur trade. It is now the second major host species of raccoons in the Baltic Republics and Byelorussian SSR.

At the end of the 19th century outbreaks of a "nervous" disease in Arctic foxes and other wild animals as well as in dogs in the Arctic regions of Russia e.g. Anadyr, Jakutia (northern Siberia) were described. This disease was called "dikovanie". The causative agent of "dikovanie" was shown to belong to Lyssavirus type 1 and is now designated Arctic Rabies.

The main host species of Arctic Rabies virus is the Arctic fox. Other species (e.g. red fox, Arctic bear, wolf, dog, reindeer) are only infected occasionally.

About 300,000 people are exposed to suspect animals each year. About 30% of them received post-exposure treatment. Countrywide about 35-50 persons are reported to die from rabies each year, 90% of them were living in the Asian parts of USSR.

3. ECOLOGY OF MAJOR HOST SPECIES

3.1 The red fox

3.1.1 Individual fox behaviour and population dynamics in a rabies enzootic area of France

The main results and hypothesis of fifteen years of red fox population studies in an enzootic rabies context are summarized hereinafter:

The monitoring by radio-checking the space used by several foxes suggest that the fox is a solitary species. Fox home ranges are permanently changing and overlapping the rims of neighbouring fox home ranges. Foxes live alone most of the time and in pairs only during the breeding season. Extra individuals are only accepted within a given already inhabited area during good seasons (peaks of voles abundance).

The foxes predominantly solitary behaviour probably not only limits contact between healthy and rabid foxes, but also favours emigration as a means of avoiding close proximity with other individuals.

Observations showed that a relatively higher proportion of one year old foxes was present in the fox populations living beyond the rabies front. Under these conditions, fox migration from beyond the rabies front into the rabies infected zone may be more
frequent. Therefore, it is assumed that a fox population in a rabies infected part of western Europe reacts to rabies induced mortality by drawing in "new" individuals from a neighbouring rabies-free area, rather than by increasing its reproduction rate.

This hypothesis is consistent with the fox abundance index recorded in a field study area where rabies waves failed to markedly reduce the size of the fox population for a number of years. It is therefore suggested that a given fox "metapopulation" should be considered as an association of "micropopulations", exchanging individuals and rabies: when one micropopulation is suffering from rabies, another is recovering from the disease, and sending emigrants into the depopulated neighbouring area. This latter area becomes progressively more densely populated and consequently more susceptible to rabies. In view of the absence in a rabies infected area of a long term reduction of the fox population size, it is suggested that rabies, when enzootic, only contribute to the control of the fox population dynamics.

3.1.2 Population dynamics of red foxes in Sweden

In northern Sweden, rodent populations fluctuate greatly from year to year. When rodents are in large numbers, most vixens produce cubs, litter sizes are large (mean 6) and most cubs also survive. When rodent populations fall, few vixens produce cubs, the mean litter size is only about 3 and the mortality rate of cubs is very high, up to 70%.

In the agricultural areas to the south, rodent populations fluctuate but less than in the north. The mean fox litter size is high in all years. The proportion of barren vixens is also high in spite of the abundant food supply. Mortality rate of the cubs is also high.

When rodent numbers are very low in the north (0.1-0.2 rodents/fox stomach content), the cubs will disperse more frequently than at times of high rodent availability.

During the first year of life, 25% of the males and 15% of the females disperse. A study of a sample of tagged adults indicated that 8% (the same % in both sexes) dispersed over 20 km. This indicates that adult foxes, as well as juvenile, could potentially play a role in the eventual spread of rabies in Sweden.

Dispersing foxes tend to move north and west. This could also contribute to the spread of rabies in Sweden should it be introduced in the southern part of the country.

Recently the fox population has been decimated by mange which was apparently introduced from Finland by foxes which crossed on the frozen Gulf of Bothnia. This event clearly indicates the potential for the introduction of rabies following the same itinerary.

Following the mange outbreak, the low fox populations now existing in Sweden may create conditions favourable to the settlement of foxes dispersing from across national borders.

3.2 Arctic fox ecology

In Arctic regions, the habitat of the Arctic fox can be roughly divided into two types: inland tundra and coastal regions. There are considerable differences in the ecology of the species depending on habitat type. In the more typical inland habitat, the large majority of Arctic foxes are of the white colour morph (> 99%) while in coastal habitat blue foxes are in the majority. In most inland habitats the major part of the Arctic foxes diet consists of rodents which fluctuate in numbers by cycles of 3-5 years.
Foxes show a numerical response to rodent availability, and due to very high fertility of the vixens, (mean number of placentals scars >10/breeding female), fox population numbers can build up very fast after a sudden decline.

In contrast, in Iceland, where seabirds are the main part of the diet by the shore, and ptarmigan and waders in the inner parts of the country, prey populations are inter-annually stable and fertility of Arctic foxes is low (5.4 ± 1.5 placentals scars/breeding vixen; N = 264). Similarly, dispersal distances are short in Iceland, on average 25-30 km in comparison to the very long dispersal distances observed in Arctic regions of North America. Also, Arctic foxes maintain their territories throughout the year in Iceland when the food situation in winter allows, while social organization may break up totally in tundra regions during winter.

It is concluded that Arctic fox ecology is by no means uniform and has to be studied in as many habitat types as possible to gain information on the overall ecology of the species.

3.3 Ecology of the raccoon dog

The raccoon dog (*Nyctereutes procyonoides*) established a permanent population in Finland during the 1960-70s. The population density in Southern Finland is at present estimated to be about 1-2/km² in autumn and < 0.5/km² in February-March, when the mating season begins. The average life span is shorter than one year due to high cub mortality, which is compensated by large litters. The mean litter size, is 9 in the Southern and 7 in the Northern parts of the permanently inhabited region. Determining limiting factors for raccoon dog populations establishment and maintenance seem to be the winter length and snow depth. In the northern uppermost regions these factors prevent the establishment of a permanent raccoon dog population. The animals are scavengers, living on food easily available such as small rodents, frogs, dead fish, worms, snails, birds eggs, carcasses and by visiting dumping sites. People frequently feed them around their summer houses with garbage, fish, etc. The male-female relationship seems to last a lifetime. Young females are tolerated in the territory, but mature males are forced to move out. The territories of neighbouring families may overlap to some extent. During the summer and autumn the animals gather considerable fat deposits, the adults increasing their weight by some 40-50% to about 8-10 kg by the end of October. In Southern Finland, hibernation usually begins in mid-November, depending on the onset of winter. Favourite hibernation sites are abandoned badger and fox dens, under buildings like barns, etc. During mild winters, hibernation is frequently interrupted and the animals move around until the cold returns. The raccoon dog as well as the fox populations in Finland are troubled by sarcoptic mange.

4. ELIMINATION OF RABIES BY ORAL IMMUNIZATION OF WILDLIFE

4.1 General principles for the elimination of rabies by oral vaccination in wildlife

Eradication of rabies by oral vaccination of Arctic wildlife (fox, raccoon dog) is feasible, economic and safe. In central Europe, 5 million doses of SAD vaccine bait have been manually distributed by hunters or dropped from aircrafts.

Control of rabies is almost immediately achieved when vaccination is carried out during the declining slope of an epidemic. Post-vaccination surveillance of rabies should be given high priority. Large areas have been freed from rabies and kept rabies-free for 4 years now. The effectiveness of wildlife vaccination can be illustrated by the example of Finland, where an imported rabies epidemic among wildlife and domestic animals was eradicated following oral immunization campaigns of raccoon dogs and foxes.
The following guiding principles relate to the oral vaccination of red foxes (*Vulpes vulpes*), and raccoon dogs *Nyctereutes procyonoides* with vaccinal baits distributed by ground placement or by dropping from aircraft:

(a) The area to be baited should be as large as possible.

(b) The baited area should be defined on the basis of natural geographic features and barriers. Where feasible the area should not be limited by political or administrative boundaries.

(c) The area should be vaccinated twice a year.

(d) The time for vaccination depends on the individual situation but it should be borne in mind that vaccination in spring and autumn is considered best.

Freezing weather should be avoided unless bait uptake and efficacy of the vaccine have been proven under these winter conditions. The selection of the most appropriate method of distribution (at ground level by hunters and/or farmers, or by air) will depend upon seasonal availability of manpower and equipment.

(e) There should be at least four vaccination campaigns during the first two years.

It is emphasized that after each breeding season the population is increased by up to 60% or 70% young animals which are susceptible to rabies infection. It is extremely important that specimen collections from the treated area continue even after rabies has apparently disappeared.

Subsequent treatment of recurring foci on a small scale is usually not effective. If necessary the whole area should be re-baited by aircraft.

(f) Local/national agencies should be prepared to continue vaccinating an area beyond the initial 2 years if rabies reoccurs or is reintroduced from neighbouring areas.

(g) When a country is invaded by wildlife rabies for the first time, the area to be treated must be larger than the apparent zone of infection. This was illustrated in the recent Finnish outbreak in raccoon dogs and foxes.

(h) The bait density needed to effectively vaccinate red foxes and raccoon dogs by manual ground placement is 15 baits/km². When aerial distribution is carried out a density of 20-25 baits/km² (depending on the habitat) should be used.

(i) Distribution by aircraft provides a more uniform coverage of large areas than ground placement, particularly in swamp areas where manual distribution is difficult.

Enthusiasm of the hunter/farmer or any other group/association (hereinafter called "cooperators") involved in manual bait distribution may decrease with each successive campaign especially if the preceding campaign(s) have been totally successful (i.e. no rabies cases reported).

A strategy for rabies control/elimination based on oral immunization of wildlife species by vaccinal baits is more cost-effective than distributing hunting bounties.

(g) "Cooperators" should be taught the criteria for the most appropriate hand placement of baits, and should avoid placing more than one bait at one location as this is not cost-effective.
(h) When it is necessary to maintain an immune barrier along an administrative border or a "cordon sanitaire" around an area, the width of the treated zone should be at least 10 to 20 km. This zone should be baited once a year preferably in the late summer or autumn, as this is the period of the highest population density and dispersal movements.

(i) When initiating a vaccination campaign in an endemic area, baiting is most effective if started immediately after an epizootic when the host species population is low.

4.2 Control of Arctic rabies by oral immunization - the Finnish example

In order to control a rabies outbreak which occurred in April 1988 in the southern part of Finland (refer to country report in paragraph 2.3) a field trial was initiated in late September 1988 in a limited area where most rabies cases were reported during the first 8-9 months of 1988. A total of 40 500 baits were distributed over 2600 km². Since rabies cases were reported in 1989 outside this area it was decided to organize a new oral vaccination campaign over a larger zone. In mid April 1989, 119 100 baits were manually deposited over 8000 km². A third and last campaign was organized in mid September 1989. On this occasion 30 000 baits were distributed over 1700 km².

The last case of rabies reported in Finland occurred in February 1989. No more cases have been reported to date in the country. Following the first campaign the recorded seroconversion rate was 73% in the raccoon dogs and 67% in the foxes. Corresponding figures for campaign two were 31% and 37%, and for campaign three, 76% and 48% respectively. Regarding bait uptake, rates recorded for the successive three campaigns were 55%, 46% and 67%, respectively.

4.3 Special considerations for the elaboration of national plans for rabies control in Arctic and sub-Arctic regions

Arctic/sub-Arctic areas are diverse, varying from flat coastal tundra to glaciated mountainous areas. Hence no single control method is or will be suitable throughout this broad region. Environmental factors should be taken into consideration for the development and implementation of a control programme including (but are not limited to): (a) topography; (b) daily, seasonal and annual temperature variation; (c) seasonal and annual sea ice occurrence; and (d) ecology of local rabies host species.

Given these variables, the selection of a strategy for rabies control must be specific to the area of concern to ensure an effective and efficient programme biologically, economically, logistically and politically.

At present, rabies control includes such traditional methods as trapping, hunting and poisoning which have been shown to be effective in limited areas and under specific circumstances. Where their impact on rabies has been limited, it was because of the high reproductive potential of the carnivore species targeted in these programmes. The effect would be especially short-lived in Arctic/sub-Arctic areas where litter sizes tend to be larger than at lower latitudes. However, even with these limitations, hunting/trapping programmes in restricted areas may be the only methods available given the environmental constraints, or may be effective in combination with other programmes such as oral immunization.

Perhaps the most serious constraint on an oral vaccination programme in the Arctic is the ambient air temperature. Present oral vaccines must be in a liquid form so that they can be absorbed through the buccal mucosa. Freezing will greatly affect the vaccine's effectiveness because it will first thaw in the stomach where earlier experimental work
has shown absorption and subsequent immunity to be very low; probably as a result of inactivation of the vaccine by the acidity of the stomach and presence of protein enzymes. In Arctic/sub-Arctic areas, air temperatures may exceed 0°C only for short periods, for example June through August. In many places however, even during the summer, daily temperature fluctuations are such that freezing occurs almost every night. Thus, the following climatic conditions must be considered:

- the continuous freezing during winter which at present will prevent an oral vaccination programme given the present state of technology, and

- the freeze-thaw cycles that can occur daily in the summer can make an oral vaccination programme ineffective.

Timing is also important when wild animal carcasses such as a beached whale or carcasses on a garbage dump are used for baiting. These are typically sought out by certain species such as the Arctic fox in winter, a time when ambient air temperature will affect the vaccine. Access to such food sources in summer will usually be limited to animals whose home range/territory encompasses that food source. Other individuals living in areas adjacent to the food source will not reach it because of territorial boundaries. Once again, a vaccination programme may have limited effect if food sources are used at sites for vaccinal bait deposits at an inappropriate time (summer) when the number of animals immunized will be insufficient to avert an epizootic.

Placement of baits in other areas has been done on foot and from aircraft. Both methods should be considered in Arctic/sub-Arctic areas. In areas of very rugged terrain, forests, or where densities may not be obvious as in a rocky habitat where carcasses may be used, application of baits along transects flown over by aircraft may be appropriate. In flat tundra areas Arctic fox dens may be fairly visible from aircraft due to the green lush vegetation surrounding the den sites in comparison to surrounding tundra vegetation. The difference is due to faecal material, urine and decomposing food acting as fertilizers for the plants. A vaccination programme could take advantage of this and place baits at den sites thus reducing the number of baits needed, while increasing the probability of immunizing a higher proportion of foxes. In most areas, and for some species the den site is the focal point during the summer before dispersal of young and adults. Animals at lower latitudes, including the boreal forest, often have numerous dens within their home range thus perhaps reducing the effectiveness of this approach. Transect distribution by aircraft may be the most efficient in these circumstances. However, in the Arctic where permafrost limits the number of dens available, a search for and placement of baits at dens may be more efficient biologically and more cost-effective.

Snow type (powder versus hard packed) could affect bait distribution because baits dropped from aircraft would sink in deep powder, thus hiding them from target animals. In any event, the temperature limitation on the use of oral vaccines make consideration of snow depth and quality only an academic exercise at this stage.

In general, large land masses should not be considered for a vaccination programme. The vast expanses of Arctic tundra require many baits and costly logistic support, and the effectiveness is limited by the highly mobile nature of, for example, Arctic foxes immigrating from other areas, including the sea ice from adjacent land masses.

4.4 Guidelines for preparedness and response to emergency situations

In the context of this report an emergency situation follows the occurrence of an outbreak of rabies in an area previously rabies-free; the outbreak usually originating from a focal introduction.
Initial actions which should immediately be taken within the infected area are the following:

(a) Experts on the disease and the mammalian vectors should be brought together. These should include all political agencies and authorities responsible for human and domestic animal health as well as wildlife management.

(b) The national government should take over all costs related to control to ensure uniform participation by local governments.

(c) Existing vaccination regulations for domestic animals must be reviewed and the legislative and economic base for action defined.

(d) The quantity of both human and domestic animal vaccines available in the country must be evaluated and additional vaccines doses must be ordered from producers, as required.

(e) The existing knowledge on wildlife vector systems in the country should be reviewed, particularly all potential host carnivore vectors known to be present in the area (e.g. red fox, Arctic fox, raccoon dog, wolf and badgers).

(f) Rabies surveillance should be established or strengthened through:

- performing early diagnoses in local laboratories and if necessary, establishment of national diagnostic facilities;
- immediately sending samples to a WHO collaborating centre for confirmation and typing with monoclonal antibodies;
- organizing the screening of specimens from all potential host species in the affected area. All sick or dead animals should be sent for diagnosis.

(g) Action should be taken to inform and educate the inhabitants of the designated infected area of the outbreak and the professional and other groups, with special reference to physicians, veterinarians, hunters, school children and other target groups.

In addition general information on rabies in the form of brochures, videotapes (available from various sources) should be used to quickly supplement the local information campaign for the general public.

(h) The need to vaccinate dogs and cats in the area and restrict their movement (as far as possible) out of the area should be evaluated.

The movements of dogs and cats should be controlled by their owners and all stray animals confined or destroyed. The number of susceptible wildlife vectors must be reduced. This can be achieved by a variety of methods such as population reduction through hunting, trapping, or poisoning can be used in small foci if feasible.

(i) Oral immunization campaigns should be initiated as soon as possible. When feasible the area to be treated around the focus should be limited by natural physiographic borders, and not by administrative boundaries. Cooperation at a national level is essential.
Procedures for planning and implementing the oral vaccination campaign should follow those described in "Principles for the Elimination of Rabies from an area by the Oral Vaccination of Wildlife" (see paragraph 4.1). In preparation for a possible rabies invasion of a rabies free country e.g. Sweden, Norway, Iceland, a preliminary baiting campaign with placebo baits should be carried out to assess bait uptake and establish systems for specimen laboratory examination.

5. STRATEGIES FOR THE MAINTENANCE OF THE RABIES FREE STATUS

These strategies consist of a set of procedures aiming at maintaining the rabies-free status of a country.

- Systematic quarantine over a long period (e.g. 4 months as practised in Sweden and Norway) is an efficient way of avoiding imports of infected domestic or zoo animals. However, its limitations regarding the introduction of wildlife-mediated rabies are obvious. In addition stringent quarantine regulations are known to foster animal smuggling.

- Rabies vaccination, when safe and potent vaccines are used, is known to protect against the disease. However, the risk persists in the absence of quarantine if imported animals are immuno-deficient, or receive a vaccine of insufficient potency, or insufficiently attenuated, or the animals are accompanied by a false certificate. Systematic testing of the immune status of imported animals by testing for the presence of rabies neutralizing antibodies could be a way of considerably reducing the duration or even de-establishing quarantine.

The cost-effectiveness of quarantine versus vaccination and control of the immune status of imported animals should be studied in rabies-free countries of the Arctic and sub-Arctic regions. For that purpose base-line data should be collected regarding the rates of: (a) animals which are not protected following vaccination, (b) animals which become rabid in spite of vaccination. The probability of an imported infected animal transmitting the disease to other animals and thereby causing an outbreak in wildlife should be evaluated. The most probable eventuality, at least in rabies-free countries with terrestrial borders (e.g. Norway, Sweden), consists in the introduction of wildlife rabies from neighbouring countries (e.g. through Finland or from the USSR).

There is a wide range of defence methods which can be applied to control the disease in imported animals: from complete import prohibition, quarantine, importation of vaccinated animals with or without quarantine and/or control of the immune status. To prevent the introduction of wildlife rabies, the establishment of a vaccination belt using oral immunization on a permanent or temporary (emergency situation) basis should also be considered.

In addition, it should be emphasized that any of the above defence measures can only be of value if an effective rabies surveillance system at national and regional level is established and if the population is adequately informed about rabies and its implications.

6. FURTHER RESEARCH

6.1 Virology

Arctic virus strains cannot be differentiated from other Lyssaviruses by using only one monoclonal antibody. However, F41 monoclonal antibody is a useful tool for
preliminary screening of rabies isolates from Arctic and sub-Arctic regions. Research on virus strains characterization should consist of:

(a) A comparison of Arctic rabies strains from Alaska, Canada, Greenland, Norway, USSR and Finland. The WHO Collaborating Centre for Surveillance Research on Rabies, of Tübingen (FRG) is willing to distribute P41 to interested laboratories for preliminary screening of isolates. It is recommended that representative strains reacting with P41, therefore thought to carry the Arctic marker, should be sent to the above WHO collaborating centre for examination with a more complete monoclonal antibody panel. These isolates should also be examined by the laboratories of origin using, whenever available, their own panel of monoclonal antibodies.

(b) An evaluation of strains carrying the Arctic marker (i.e. positive with P41) from non Arctic parts of the world (e.g. USSR and Nigeria).

(c) Undertaking RNA sequencing of nucleocapsids of a representative Arctic virus strain. The WHO collaborating centre in Tübingen would be ready to undertake this work.

(d) If feasible, serological surveys should be attempted. Rabies positive serum samples should be tested in competitive antibody binding assay employing Arctic rabies virus markers for geographic studies of rabies infections in Arctic and sub-Arctic regions.

Further experimental studies should be carried out on:

(a) The susceptibility to rabies of the major Arctic animal species including routes of infection and particularly the possibility of infection by ingestion of infected carcasses preserved in permafrost.

(b) The major host species such as Arctic fox and raccoon dogs with special emphasis on the incubation period and the duration and symptoms of clinical illness including the two colour morphs (blue and white) of the Arctic fox. In addition, the duration of virus excretion and the possibility of recovery from the disease should be studied in the Arctic fox.

6.2 Ecology of rabies host

Three eco-epidemiological systems and three research topics were identified. Any of these systems is characterized by: the main vector species, the geographical areas, the virus strain (or isolate), the other rabies susceptible species.

The three main research topics to be taken into consideration in each system are: the spread of the virus with reference to biogeographical and climatic factors; the ecology of the vectors (i.e. interspecific relationships of the species directly or indirectly involved in the epidemiology of Arctic rabies); the behavioural-ecology of the different species (i.e. auto-ecology and behaviour of the few carnivore mammals known or suspected to host Arctic rabies).

A review of the three different eco-epidemiological systems identified on the basis of the above characters in the Arctic and main topics to be studied is given in the following.
6.2.1 System 1

In System 1 the main host species are the raccoon-dog and/or red fox. System 1 is encountered in Finland, Poland, and USSR (deciduous forest/taiga Northern-temperate climate) and the virus strain involved is thought to be the Polar strain. Other species can be infected in wildlife (e.g. badger, bats).

The main topics which should be studied are:

- the spread of the disease taking into consideration the freezing/thawing times of sea waters in the Gulfs of Finland and Bothnia, and registration statistics, forecast modelling should be compiled and analyzed;

- the interaction between different wildlife species (e.g. red fox, raccoon dog, wolf, and badgers) and the contacts with man and domestic animals (i.e. overlapping home ranges of these wildlife species between each other and with human/cattle/pet activities);

- the use of dens (sharing by species or competition/exclusion of dens) and hierarchies for access to carcasses;

- the potential for interspecific transmission of rabies virus (including differences in healthy/rabid individual behaviour);

- the behavioural-ecology and behavioural strategies, such as use of space, habitat and time, dispersal, reproduction (behaviour, seasonality), food habit and feeding strategies; and

- the population dynamics taking into account the reproduction (rate, success, etc.) and mortality.

In studying System 1 the following aspects should receive special attention:

- the methodology of population density estimates;

- the impact of hunting and human control of host species population and recovery rates.

6.2.2 System 2

In System 2 the main host species are the Arctic/red foxes and domestic dogs and can be found in mainland North America and Eurasia in the far-north (tundra/taiga in Arctic/sub-Arctic climates).

The virus strain involved is the Polar strain and other infected wildlife species are wolf, reindeer/caribou, polar bear, river otter, wolverine and American mink.

The main topics which should be further studied are:

- the spread of the disease with regards to the freezing/thawing of rivers and oceans, as well as sea-ice movements. A review of the existing information on the subject is needed within the rabies context;

- modelling with respect to the changes expected from the "green house" effect on ice formation and movement (notably the possible decrease of the frequency of ice bridge and ice flows between mainland and islands) as well as species distribution and
dispersal (notably extension of the range of fox and raccoon-dog toward northern countries);

- the interaction between the different host species involved (e.g. Arctic/red foxes/wolf/domestic dog) with special reference to seasonal and annual variations (quality and quantity) of food availability;

- the preservation of rabies virus in frozen carcasses in a cold climate and the epidemiology of other diseases including parasitic transmission (for comparison either as a model or a marker, e.g. Echinococcus multilocularis, mange, infectious canine hepatitis and distemper virus);

- the behavioural ecology which is similar to that of system 1 with the exception of dog ecology in areas where they are free-roaming in summer;

- the food ecology which should be considered with special reference to baiting (attractiveness of frozen baits, and foraging behaviour relative to food availability as a way to predicting success of baiting campaigns).

6.2.3 System 3

In System 3 the main host species is the Arctic fox and perhaps the (domestic dog) and is found in Greenland, Iceland, Spitzbergen and other islands. It is characterized as an Arctic, maritime ecosystem (coastal vegetation, Arctic maritime climate). The virus strain involved is the Polar strain (different isolates need to be characterized). The other infected species are: seals, reindeer/caribou, and polar bear.

Topics which need to be studied are as follows:

- The spread of rabies with reference to the same items as in system 1, plus the role played by ships, aircraft and animal smuggling in the continual cycle of extinction and re-introduction of virus.

- The interaction between the Arctic fox and domestic dog as well as secondary susceptible species such as mink, bats and seals (living as well as carcasses).

- The behavioural ecology (see system 1 or 2) with special reference to the characterization of genetically isolated populations.

6.3 Epidemiology of Arctic rabies

Arctic rabies is defined as a disease of wild (Arctic fox and others) and domestic (dog and other carnivores) animal species caused by a serotype 1 Lyssavirus belonging to type 1 within the Arctic and sub-Arctic regions of the northern hemisphere.

The animal species supporting rabies epizootics are the Arctic fox, the red fox, the raccoon dog, the domestic dog and perhaps the wolf and coyote. In addition all mammalian prey species which are preyed on by the rabies hosts may be affected.

The questions which should be addressed are:

- the prevalence of Arctic virus and rabies antibody in carefully selected samples from carnivores and humans;

- the patterns and mechanisms of the disease spread (see paragraph 6.2 - Ecology or rabies host);
- the mechanisms of virus maintenance in Arctic carnivore populations; of virus transmission, species susceptibility and pathology and virus resistance under ambient conditions (see also paragraphs 6.1 and 6.2);

- the level of transmission from carnivores to human beings;

- the appropriateness of conventional rabies diagnostic tests;

- the eventual relationships between Arctic rabies and other rabies cycles.

6.4 Control of Arctic rabies

The major areas which require further research are:

- the baiting strategies adapted to Arctic/sub-Arctic areas.

- the development of enteric (or other) vaccines that will not be adversely affected by freezing;

- the environmental factors that could affect the success of a control programme including (but not limited to): (a) physical oceanography with special reference to freezing/thawing cycles, oceanic currents and ice distribution and movements which may affect movements of target species; (b) ecological studies that will yield insight into interspecific relationships and general co-adaptation of target species and the rabies virus to Arctic/sub-Arctic conditions of relevance to control programmes; and (c) studies of the social behaviour of target species to increase our understanding of elements that would affect the efficiency and effectiveness of a control programme.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Specific recommendations

7.1.1 National and international surveillance of Arctic rabies

In order to establish a system of rabies control through active surveillance in each country of the region it is necessary to:

- define and update current national surveillance systems (e.g. by incorporating a few additional questions in the WHO World Rabies Survey questionnaire);

- establish national rabies surveillance in each country concerned with Arctic rabies. Training sessions in proper surveillance techniques should be organized (i.e. reporting of cases by species and areas, data processing, handling of specimens);

- decide which methods of collection and transportation of specimens should be used;

- the virus isolates should be characterized;

- forward information on the number of animals examined in each major species (together with the number of positive and negative) and send strains to the relevant WHO collaborating centers for incorporation of data in the "Rabies Bulletin Europe" and cross-checking of laboratory results;
7.1.2 Virology

WHO should investigate with laboratories located in countries infected by Arctic rabies the possibility of carrying out the research projects mentioned in paragraph 6.1. Potential candidate countries are USA (Alaska), Canada and USSR. France would also be a potential host laboratory for the study of Arctic rabies virus pathogenicity in raccoon dogs.

7.1.3 Ecology

Emphasis should be placed on the following ecological studies:

- Intraspecific relationships of the most important vector species, particularly the sharing of habitat (especially dens), and food (especially frozen food in winter);
- Dispersal of host species, preferably by the use of satellite radio-telemetry;
- Improvement of methodologies to calculate density estimates;
- Preparatory tests on bait marker, bait delivery and bait uptake by host species in different habitats according to season;
- Scientific contacts with researchers working on climatological effects on the distribution of carnivores and their prey, as well as ice-formation and movements of pack-ice on the oceans as a way of dispersal of rabies carrier animals.

7.1.4 Epidemiology

Information on Arctic rabies should be collected in collaboration with local Arctic hunters and trappers. There is a special need to:

- Improve and intensify rabies surveillance;
- Sample all carnivores found dead or killed by hunters and trappers in selected areas for virus isolation and virus isolation with monoclonal antibodies (Mabs);
- Exchange isolates between laboratories for biological and Mabs characterization (Mab, biology);
- Collect biological data from rabid animals and blood samples from Arctic carnivores;
- Survey Arctic hunters and trappers for antibody prevalence;
- Share information between countries.

7.1.5 Maintenance of the rabies free-status

Rabies-free countries of the region should apply methods most appropriate to their specific situation (i.e. geographic identification of the most probable way of introduction and modalities for the establishment of the disease in wildlife). The ultimate objective being to maintain their rabies-free status. The cost and other negative effects (e.g. possible animal smuggling) related to ensuring adequate defence against rabies should be compared to those necessary to control and eliminate a rabies outbreak. This calculation should also take into consideration the impact of the disease on animal and human health. Contingency plans for the control and elimination of rabies
in domestic (e.g. by parenteral vaccination) and wildlife species (by oral immunization) should be drafted as a precaution. Permanent or temporary (at the border with a newly infected area where oral immunization campaigns are undertaken) oral vaccination belts should be established in strategic areas. Stock piles of rabies vaccine for parenteral immunization of animal and man should be maintained in all areas.

1.2 General Recommendations

Countries, which currently have little or no rabies, should be encouraged to form a national rabies coordinating committee to bring together agencies responsible for human and domestic animal health, as well as wildlife management.

This committee should be in charge of the formulation of contingency plans should wildlife rabies outbreaks occur, and the coordination of preliminary research on wildlife rabies control measures, including organization of campaigns with placebo baits (see chapter 4, paragraph (i)) for training and research purposes.

A subgroup of the Arctic Rabies WHO Working Group should be formed to coordinate research efforts on Arctic mammalian rabies host species ecology and Arctic rabies epidemiology. The group should include scientists from all participating countries in the holarctic region. It was suggested that two coordinators be nominated: Dr P. Hersteinsson for the palearctic region and Dr E. Pollow for the nearctic region.

Exchange of information between countries of the holarctic should receive special attention especially in border areas. Following the occurrence of the rabies outbreak in Finland it is recommended that cooperation projects for strengthened rabies surveillance be initiated through central services with local authorities in the Khuse peninsula (Norway/USSR) and along the Finland/USSR border.

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