825 NINA Oppdragsmelding

Captive-breeding, population supplementation and reintroduction as tools to conserve endangered arctic fox populations in Norway: detailed proposal and progress 2001-2004

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Abstract

Within its Holarctic distribution, the global population of Artic foxes (*Alopex lagopus*) appears to be large and stable, however the populations of Fennoscandia were already endangered in the late 1920's. This led to their protection in Sweden, Norway and Finland in 1928, 1930 and 1940 respectively. Despite their protected status there has been little or no indication of population recovery. Based on numbers of documented reproductions we estimate that there are no more than 50 adult arctic foxes in Norway. These animals are distributed widely, thus occurring in low actual numbers with gaps between the different populations.

Why arctic fox populations have failed to recover after their protection could be because of the competition from red fox (*Vulpes vulpes*) together with demographic collapse as a result of population decline in a fragmented landscape. Because the current population is at such a critical stage, it is important to initiate conservation actions at once. Conservation actions that can be taken include (1) Supplementary feeding to increase survival and reproduction, (2) Red fox control to reduce competition and intraguild interactions, and (3) Population supplementation / reintroduction to restore connectivity. Conservation actions (1) and (2) have been conducted in Sweden and Finland, but existing experience is not yet sufficient to conclude if these actions are effective. Conservation action (3) is therefore proposed.

Although translocation of arctic foxes is generally to be preferred over the use of captive-bred animals, there are no suitable sources of wild foxes for translocation. Populations on Svalbard are not suitable due to genetic differences and the occurrence of rabies. Populations in Siberia are also not suitable due to the occurrence of rabies. Furthermore animals from captive-breeding have been used successfully in many situations for many species.

The arctic fox captive-breeding programme consists of carefully adjusting and developing the method that functions best for breeding wild-caught animals in captivity. Pups born in captivity will be released with pre-release training following the experience of a successful swift fox (*Vulpes velox*) reintroduction project in Canada. Release sites are chosen based on the available data on arctic fox ecology, former den availability and habitat distribution. All released foxes will be post-released monitored with help of expandable radio-collars. Also dens will be monitored annually to detect changes in population development. Defining the success of the captive-breeding programme will be based on (1) Survival, (2) Pair formations, and (3) Population growth. Different expertises and institutions, from Norway, Sweden and Finland are pooled to determine which actions seem to be most successful and thus enhance our success with the reintroduction programme.

Foreword

The arctic fox is classified as highly endangered and has become extinct in many mountain plateaus during recent decades. It is likely that the species will not survive without active help. Potential actions are supplementary feeding, red fox control and captive breeding for release. Trials with all these actions have now been started in Norway.

The captive breeding programme had to start while there still were wild arctic foxes to left to establish a breeding stock. It is obvious that such a project has to overcome many challenges to succeed. However, experiences from many similar programmes abroad, gives reasons for optimism. For example the North-American swift-fox captive breeding programme which started in 1972 has recently had success in re-establishing wild populations even if they had to rely on qualified guesses about the causes of the species reduction and local extinction. A common characteristic for all captive breeding & release programmes is that they take a long time and have high costs. However, the arctic fox's strong symbol value as well as its ecological role as a key species in the Norwegian mountains requires us to do our best to save it from regional extinction.

Trondheim August 2004
Arild Landa
Project manager

Forord

Fjellreven regnes som direkte utrydningstruet og har forsvunnet fra mange fjellområder i løpet av de siste ti-årene. Det er trolig at arten ikke vil overleve uten aktiv hjelp. Aktuelle tiltak er støtteforing, reduksjon av rødrevbestanden og oppdrett av fjellrev for utsetting. Forsøk med alle disse tiltakene er igangsatt i Norge i dag.

Arbeidet med innfanging av ville fjellrevvalper og avl måtte igangsettes mens det ennå fantes ville fjellrever til å danne grunnlaget for en avlsstamme. Det er åpenbart at det er store utfordringer som må overvinnes for å lykkes med et slikt prosjekt. Men erfaringer fra mange lignende prosjekter i andre land gir grunn til optimisme. For eksempel i det nordamerikanske swift-fox prosjektet (Cochrane Ecological Institute) som startet i 1972 har en hatt stort hell med å reetablere bestander til tross for at årsakssammenhengene til dens tilbakegang og lokale utryddelse kun bygget på kvalifisert gjetning. En fellesnevner for slike prosjekter er at det tar lang tid og koster mange penger. Men fjellrevens sterke symbolverdi og økologiske rolle som nøkkelart i norske høyfjell forplikter oss til å gjøre vårt beste for å redde den fra regional utryddelse.

Trondheim august 2004
Arild Landa
prosjektleder

Contents

2 Arctic fox distribution and status worldwide

Throughout their range arctic foxes (*Alopex lagopus*) are confined to tundra and alpine habitats, probably being excluded from more productive regions by interference competition with red foxes (*Vulpes vulpes*) (Hersteinsson and Macdonald 1992, Linnell et al. 1998). Arctic foxes have a Holarctic distribution, being found on the mainland of Scandinavia, Siberia, Alaska, Canada, plus the islands of the Canadian arctic archipelago, those off the Siberian coast, some of those in the Bering Sea, the Commandor Islands, Greenland, Iceland and Svalbard (Garrott and Eberhardt 1987, Ginsberg and Macdonald 1990). In most regions arctic foxes are so abundant that they are commercially exploited for their furs. Regulation of trapping is very limited, however, there are not any reports of serious population declines from areas where they are harvested (Ginsberg and Macdonald 1990). The total Holarctic harvest probably lies between 50 000 and 100 000 foxes each year (Banikov 1970, Ginsberg and Macdonald 1990, Kim Poole pers. comm.). One of the few populations reported to be in decline is on Mednij Island (one of the Commandor Islands off eastern Russia). Here an epidemic of an ear mite (originally transferred from domestic dogs) has caused heavy juvenile mortality and a widespread population decline. The effect of treatment is currently being evaluated (Goltsman et al. 1996). A decline in Iceland has been halted and the species is now protected (Pål Hersteinsson pers. comm.). The populations on the small arctic islands of Bjørnøya and Jan Mayen close to Svalbard were trapped to extinction in the first decades of the 20th century and have not recovered (Fuglei et al. 1998, Rinden 1998). Apart from these cases, the global population appears to be large and stable (Ginsberg and Macdonald 1990).

The arctic fox populations of Fennoscandia were first recognised as being endangered in the late 1920's (Lönnberg 1927, Sømme 1932, Høst 1935). This lead to their protection in Sweden, Norway and Finland in 1928, 1930 and 1940 respectively. Since protection there has been little or no indication of population recovery (Olstad 1945, Haglund and Nilsson 1977, Østbye et al. 1978, Pedersen et al. 1986, Frafjord 1988, Hersteinsson et al. 1989, Angerbjörn et al. 1995, Kaikusalo and Angerbjörn 1995). The Norwegian situation has been reviewed several times (Pedersen et al. 1986, Frafjord 1988, Frafjord & Rofstad 1998, Linnell et al. 1999).

3 Historic distribution in Norway

Evidence from excavations of natural deposits and archaeological sites indicates that arctic foxes have had a more or less continual occurrence in Norway since the late Pleistocene. The oldest remains date from 36000 years ago, and there are many finds from during the last 5000 years (Frafjord and Hufthammer 1994). In the last few centuries arctic foxes were found throughout all the main alpine regions, and many of the smaller alpine patches, from Setersdal in the south to the Varanger peninsula in Finnmark in the north. This former distribution can be reconstructed from historical records and the existence of former dens. It is not possible to calculate the size of the original population because the hunting and bounty payment statistics do not differentiate between red fox and arctic fox. However, a few anecdotal reports give us reason to believe that the former population was large. For example, in 1880-81 almost 300 arctic foxes were trapped on the Varanger peninsula by 4 hunters, 126 arctic foxes were trapped in Ulvik municipality (Hardangervidda) in 1887, 90 arctic foxes were trapped in Dalsbygd (Forelhogna), Os municipality in a single summer around the turn of the century, and 2000 arctic foxes were estimated as being captured annually in Norway between 1879-1911 (Collett 1912, Frafjord 1988).

Because arctic foxes reuse dens over periods of decades, or even centuries, the structures become very visible in the landscape, because of the fertilization and excavation. For example, many dens first described in the 1930's are easily recognisable today. These dens have been extensively mapped in most mountain areas and give us an indication of the size of the previous population. The National Database currently contains over 400 known former arctic fox dens *(Figure 1)*, although most have not been in use for decades.

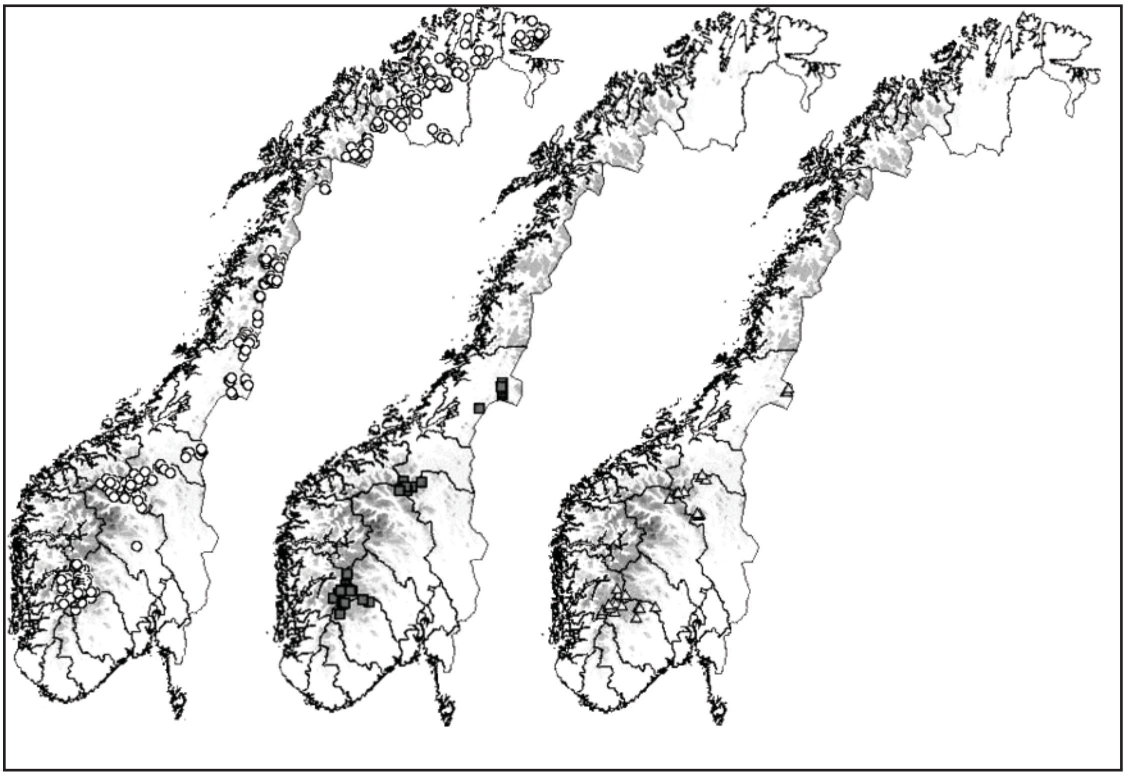

Figure 1. Known distribution of arctic fox dens, red fox dens, and dens of unknown origin in the alpine habitats of Norway. Data based on National Monitoring Database as of end of 2003.

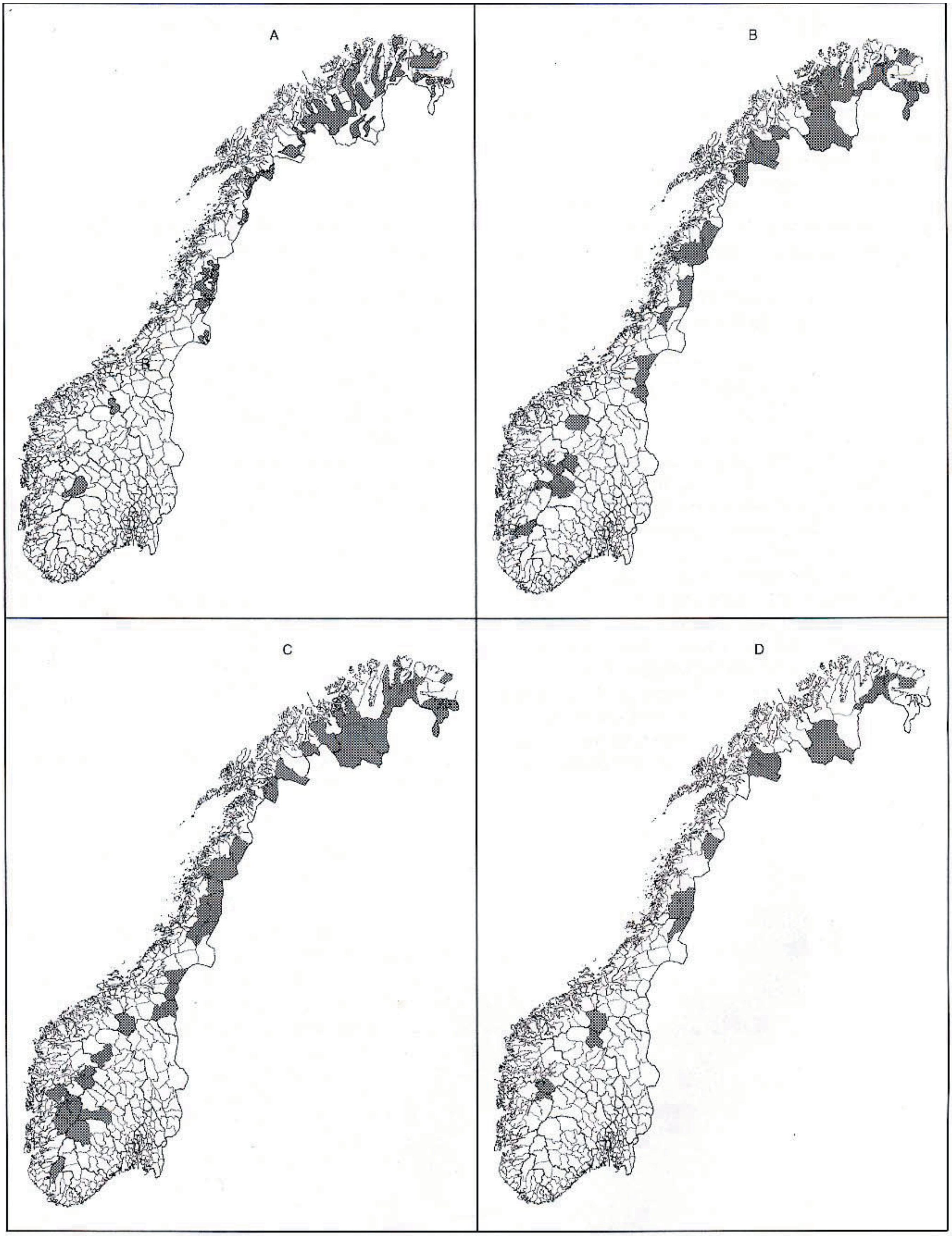

Figure 2. Changing distribution of arctic foxes in Norway 1940-1997.
(a) 1940 (Olstad 1945)
(b) 1970-80 (Pedersen et al. 1986)
(c) 1981-86 (Pedersen et al. 1986, Frafjord 1988)
(d) 1988-97 (Linnell et al. 1999)

4 The original decline - pre1930

There is general agreement that direct persecution lead to the original decline in arctic foxes. The existence of both a government bounty, and very high fur prices, in the first 3 decades of this century lead to a very intensive trapping effort (Østbye and Pedersen 1990). Commentators in the late 1920's and early 1930's discussed if arctic foxes still existed in Scandinavia or not (Lönnberg 1927, Høst 1935). Even after protection there is some evidence that illegal trapping continued and that arctic foxes may have died after consuming poisoned baits or caught in traps that were aimed at other species like red fox or wolverine before such practices were banned in subsequent decades (Olstad 1945, Østbye et al. 1978).

5 Regional development 1930 - 1988

The data available to chart the development of arctic fox populations during this period in Norway is very limited. Questionnaire surveys of municipal game managers were made in the early 1940's, 1972, 1979-80 and 1985 (Olstad 1945, Pedersen et al. 1985). Various research projects have been operating from time to time; Hardangervidda was studied from 1959 to the mid 1980's, and Sylane during the 1980's. Frafjord (1988) collected reports from throughout Norway between 1981 and 1985.

The results of these studies are summarised in the maps in *Figure 2*. Throughout the period there appears to have been very little change in the general distribution of breeding arctic foxes in Norway. However, what the early maps *(Figure 2 a,b)* do not reveal is the very few individual records that lie behind this distribution pattern. The data from Frafjord (1988) is the first which shows that throughout south Norway there were only 12 documented reproductions between 1981 and 1985 *(Figure 2 c)*. The most recent data *(Figure 2 d)* also confirms this conclusion (see next section). In short, following protection, arctic foxes have maintained most of their former distribution, but appear to have existed at a constant low population level throughout the period. There has been no sign of any recovery during the post-protection period (Østbye et al. 1978, Frafjord 1988).

6 Present distribution and status (post 1988)

Data available to evaluate the recent status of arctic foxes come from various sources. A field research project was run by NINA in Snøhetta from 1988-1995. From 1993-1997 Hardangervidda, Snøhetta, Børgefjell and Dividalen were included in the Terrestrial Monitoring Program (TOV) (DN 1989, 1997), with additional, but less regular, monitoring and surveys in Saltfjellet, Trollheimen, Forollhogna, Knutshø, Reinheimen, and Rondane. From 1998, arctic foxes were removed from the TOV program, but it has been

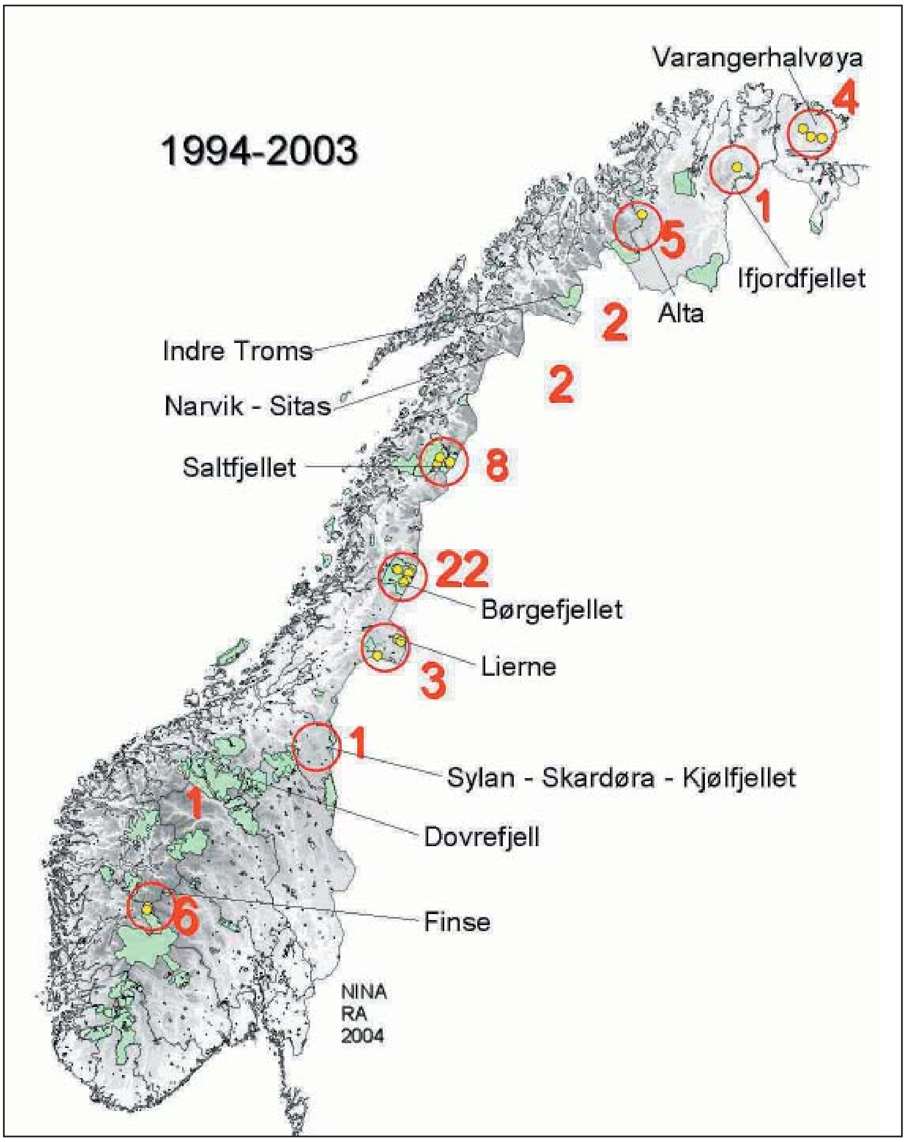

Figure 3. Distribution of known arctic fox reproductions in Norway in the period 1994-2003 within the different monitoring areas.

Table 1. Minimum number of documented arctic fox reproductions in Norway, Sweden and Finland in the 5 year period 1999-2003. Data is given per geographic area, arranged from north to south along the Scandinavian peninsula - where habitat crosses the border the data are presented on the same line. The linear distance between the most northern and most southern reproductions is around 1600 km. Data are from the Norwegian National Monitoring Program's database, Frafjord & Rofstad 1998, and Angerbjörn et al. 2003 (with update from http://www.zoologi.su.se/research/alopex/homesefalo.html).

Norway	1999-2003	Finland	1999-2003	Sweden	1999-2003	Total
Varanger Peninsula Isfjordfjellet	4 1	 Paistunturi – Kaldoaivi[5]	 0			4 1
Alta	1	Pöyrisjärvi – Käsivarsi	1			2
Indre Troms[1]	0			Råsto	1	1
Narvik – Sitas[2]	0			Kebnekaise - Sitas Arjeplog – Nationalparksblocket	2 2	2 2
Saltfjellet	5			Vindelfjällen	4	9
Børgefjell	9			Frostviken – Stekenjokk – Marsfjället	1	10
Lierne	3					3
Sylane – Skardsøra – Kjølfjellet	1			Härjedalen	9	10
Dovrefjell[3]	0					0
Finse	6					6
Hardangervidda[4]	0					0

Footnotes: Last known reproduction was in 1 = 1997, 2 = 1995, 3 = 1994, 4 = pre 1990, 5 = 1996.

possible to continue monitoring in Hardangervidda, Snøhetta and Børgefjell with funds from DN and the various county management offices. Reports from hunters, mountain wardens, and wildlife photographers make up the rest of the material. Given the large number of people that hunt, fish and hike in the Norwegian mountains each year, and the large degree of media interest that has been centred on arctic foxes, we believe that these latter reports, or the lack of them from many areas, are a very valuable source of information. Virtually, all local contacts involved in other NINA activities in the mountains, such as reindeer monitoring, have been interviewed about arctic fox occurrence. Frafjord & Rofstad (1998) have summarised available data for Nordland, Troms and Finnmark counties between 1987 and 1997.

Since 2003, arctic fox monitoring has been reorganised with a central database at NINA with the wardens from the State Nature Inspectorate organising the field work. The goal is to check as many dens as possible each year throughout Norway. The central database is currently in a phase of gathering all existing knowledge from a variety of sources, so that we can hopefully backdate many dens to the early 1990's. Therefore, the present data presented here is also somewhat preliminary.

The summary results *(Figure 3, Table 1)* are therefore not the result of systematic monitoring with equal effort in all areas. Furthermore, we cannot claim to have located all dens, or observed all reproductions. However, during the last decade our knowledge of dens has increased exponentially – but very few of the new dens that we find contain arctic foxes. It appears that the active dens are well known to local people and mountain wardens such that they entered the monitoring program at an early stage, and that subsequent finds have just been of dens that have not been active for decades. The possible exception to this is in Finnmark County, where previous knowledge was poor, and several new finds contain breeding arctic foxes. Furthermore, in some areas where arctic foxes use stone dens rather than the conventional excavated dens it can be hard to document reproduction using den inventories. On the balance, however, we feel that we have a good overview of the main areas of active reproduction.

It appears that arctic foxes are still present throughout most of their former distribution, although gaps are starting to appear. The Dovrefjell population appears to have gone extinct in the mid 1990's, leaving a gap of 300-400 km between the animals that occur around Finse, and those in the Swedish Sylane / Härjedalen population. Despite this wide distribution, the actual numbers of arctic foxes still present are very small. The Børgefjell population at the border of Nord-Trøndelag and Nordland counties stands out as the only population with more than 10 documented reproductions in the 10 year period 1994-2003.

Many of the Norwegian populations extend over the border into Sweden and Finland – but the results of monitoring in these countries do not indicate that they harbour larger arctic fox populations. In fact, arctic foxes are almost extinct in Finland, and the results from Sweden have been similar, or less, than those in Norway during recent years. In the extreme north, there is a very uncertain link to Russian populations on the Kola peninsula. However, the status of Kola arctic foxes is very uncertain, and the circumstantial data that exist indicates a small population, confined to the eastern part of the peninsula.

From these numbers of documented reproductions we estimate that there are no more than 50 adult arctic foxes in Norway, with Sweden probably containing a similar number, and perhaps another 10-20 animals being present in Finland. The trend appears to be slowly decreasing, and certainly there is no sign of unassisted recovery in any areas. It therefore appears apparent that unless there is some form of active intervention it is only a question of time before Fennoscandian arctic fox populations become extinct.

7 Searching for an explanation: Background ecology

Arctic foxes and their main prey, lemmings *(Lemmus lemmus)*, have been intensively studied in Fennoscandia, probably more than anywhere else in the world (e.g. Angerbjörn et al. 1995, 1997; Barth et al. 2000; Dalen et al. 2002; Frafjord 1986-2003; Strand et al. 1999, 2000; Tannerfeldt et al. 2002; Landa et al. 1998). As a result the general ecology of the species is well known. The mountains of Fennoscandia represent a rather special ecological situation for arctic foxes. Throughout most of their range arctic foxes either inhabit the massive stretches of continuous arctic tundra along the northern edge of Siberia and North America, or else arctic island ecosystems. In Fennoscandia, arctic fox habitat consists of a series of naturally fragmented "habitat islands" of alpine tundra habitat, surrounded by forest. This unique situation leads to a fragmented population that has a very long interface with habitat where a potentially superior competitor (the red fox) lives. From the point of view of prey base the Fennoscandian alpine tundra also differs from arctic tundra in that only one lemming species exists (most areas of the holarctic tundra have at least 2 species) and there is an absence of colonial waterbirds like geese and ducks. Alternative prey present include several vole species, hares *(Lepus timidus)* and reindeer *(Rangifer tarandus)*. The habitat differs from the high arctic islands in the general absence of both large seabird colonies, and a shoreline from which prey can be scavenged. Also these island populations are insulated from competitors. The Fennoscandian arctic fox population is also special in that rabies, a disease found in almost all other mainland arctic fox populations is absent (Mørk & Prestrud 2001).

Lemmings in Fennoscandia show a great deal of inter-annual variation in population density, a pattern that at least in certain periods is more or less cyclic, although the period and regularity vary (Angerbjörn et al. 2001). Accordingly, arctic fox reproduction varies more or less in phase with the lemming cycle, with most reproduction and the largest litters in years that coincide with peaks in lemming density (Angerbjörn et al. 1995; Strand et al. 1998). However, the fact that arctic foxes can utilise other foods (such as hares, birds, carcasses etc.) implies that they can also produce smaller litters in years with medium densities of lemmings, or when other rodent species peak. There can also be a degree of fine scale geographic variation in the lemming cycle, so arctic fox reproduction is not always synchronised over wide geographic areas.

These ecological factors all serve to increase Fennoscandian arctic fox vulnerability to extinction as they fragment the subpopulations, increase their exposure to potential competitors and induce a reliance on a very narrow, and widely fluctuating, prey species. Modelling by Loison et al. 2001, indicates that arctic fox populations have an intrinsically high extinction risk when treated as isolated populations – leading the authors to speculate that inter-population connectivity might be crucial to ensure long term viability (Linnell et al. 1999).

8 Searching for an explanation: Hypotheses

Scientists have been speculating about why arctic fox populations have failed to recover following more than 70 years of protection (Haglund and Nilsson 1977, Hersteinsson et al. 1989). A number of hypotheses have been generated that can be grouped into two main categories; those that are centred around changes in the alpine environment, and those that are centred around arctic fox demographics (Hersteinsson et al. 1989).

8.1 Changes in the alpine environment.

There is no doubt that there have been many dramatic changes in the alpine ecosystem during the last 100 years. Many of these are directly due to human influence through hunting, grazing, infrastructure development, or indirectly through global climate change. The relevant question is – have any of these changes been of such magnitude that it has rendered the alpine ecosystem unsuitable for arctic foxes?

8.1.1 Extinction of large predators.

Wolves (*Canis lupus*), bears (*Ursus arctos*), lynx (*Lynx lynx*) and wolverines (*Gulo gulo*) were heavily persecuted during the 19th and early 20th centuries to the extent that populations were driven to the edge of regional extinction. Although there has been a widespread recovery of wolverines in the alpine ecosystems of Fennoscandia (Landa et al. 2000), wolves have yet to return, and given current political attitudes (due to livestock depredation conflicts) it is unlikely that they will be allowed to recover in the alpine ecosystem at all. It has long been speculated that arctic foxes obtained food by scavenging on the kills of large ungulates made by these larger predators. Linnell & Strand (2002) have reviewed the evidence for and against the role of scavenging and conclude that there is very little direct evidence for it being of such importance that its absence would prevent arctic fox recovery.

8.1.2 Pollution.

Levels of heavy metal pollution and radiation has been surveyed in Norwegian arctic foxes and compared to levels in Svalbard and Siberian arctic foxes. Although all pollutants were detectable in Norwegian arctic foxes, they were at levels much below those of other healthy arctic fox populations (Svalbard and Siberia). This indicates that it is unlikely that pollutants are having a significant effect on Fennoscandian arctic foxes (Strand et al. 1998)

8.1.3 Disease.

Although surveys for diseases have not been widely conducted, and results are mainly from captured pups (Aguire et al. 2000; Atle Lillehaug pers. comm..) there is little indirect indication for disease processes operating in wild arctic foxes. Survival of radio-collared and ear-tagged foxes has been good, and all captured animals have appeared to be in good health. Most importantly there is no evidence for a widespread epidemic of scabies that has decimated the lowland red fox populations since the mid 1970's, apart from one isolated (and rapidly treated) episode in Sweden in the mid 1980's (Klæsson 1987; Mörner 1988).

8.1.4 Competition with red foxes.

Current theory states that exploitative and aggressive competition with red foxes sets the lower (in latitude and altitude) limit for arctic fox distribution (Hersteinsson & Macdonald 1992). There is abundant evidence from the wild and captivity to indicate that red foxes are dominant over arctic foxes, and that in some cases they can kill arctic foxes (Frafjord et al. 1989; Rudzinski et al. 1982; Schamel & Tracy 1986; Korhonen et al 1997). From the alpine ecosystem of Fennoscandia there is abundant evidence that red foxes have begun to occupy lower lying former arctic fox dens (Linnell et al. 1999; Dalerum et al. 2002; Frafjord 2003). There is also evidence that on a fine scale the presence of red foxes leads to the avoidance of these areas by arctic foxes (Tannerfeldt et al. 2002) and that both species have very similar diets (Frafjord 2000; Elmhagen et al. 2002; Linnell et al. unpublished data). Therefore, there is clearly potential for both exploitative and aggressive interactions between the species. The question is, are there enough red foxes present in the alpine ecosystem to exclude arctic foxes? Preliminary results from Sweden indicate that lethal control of red foxes may allow an increase in arctic fox activity locally (Angerbjörn et al. 2003). However, in some of the Norwegian populations we have observed arctic fox decline in the absence of red foxes, while other populations have survived, despite the constant presence of red foxes. It appears that the relationship is subtle and may well vary between different areas – although there is broad consensus that the lower lying regions of former arctic fox habitat may well have become lost to arctic foxes due to red fox presence.

8.1.5 Climate change.

The main potential effect of climate change is through its effect on red foxes. If climate warming increases the productivity of the alpine ecosystem this may allow red foxes to expand their range into the higher altitudes, thus shrinking the potential distribution of arctic foxes. There is evidence for both a lengthening and shortening of the growing season in different parts of the Fennoscandian peninsula (Høgda et al. 2001), and data on treeline development is complex and often contradictory (Aas & Faarlund 1995, Hofgaard 1997; Kullman 1993, 2001; Oksanen et al. 1995), indicating that the effect of climate is complex. It is clear, however, that any warming of the climate is likely to be detrimental to arctic foxes in the long term.

8.1.6 Changes in rodent cycles.

Arctic fox reproduction is directly linked to the availability of food, especially the fluctuating populations of lemmings (Angerbjörn et al. 1995; Strand et al. 1999). In many areas during the last decade there has been a clear absence of significant peaks in lemming abundance causing many people to speculate about the possible role of lack of food in arctic foxes decline. However, long term analysis of qualitative data (Steen et al. 1990; Angerbjörn et al. 2001) has shown that the pattern of lemming fluctuations is far from being a perfect cycle, and that there have been prolonged periods without peaks in previous decades. Therefore, there is no firm evidence that the rodent cycles have collapsed, although it does remain a topic requiring monitoring (Strand et al. 2002). However, it may well be unfortunate that there has been a coincidence between a period without a peak and critically low arctic fox populations. For example, the Dovrefjell extinction occurred in a period without lemming peaks.

In an attempt to insulate remnant arctic fox populations from the lemming induced fluctuations, efforts have been made in Sweden to feed arctic foxes in summer and winter. These efforts have been shown to increase den occupancy, reproduction, litter size and short term pup survival (until weaning) – but no longer term effects have been documented yet (Angerbjörn et al. 1991, 2003; Tannerfeldt et al. 1994).

8.2 Changes in arctic fox demographics

This set of hypotheses is centred around the fact that pre-protection overharvest led to fundamental disruption in the demographics of Fennoscandian arctic fox populations – which has lead to their entering an extinction vortex.

8.2.1 Inbreeding.

Theory predicts that small and isolated populations should become inbred with time, and that this inbreeding can potentially lead to depressed vitality (reproduction, survival etc.). However, while inbreeding depression has been well documented in captive populations of carnivores, including farmed arctic foxes (Valberg 1993), evidence for it in wild populations is very limited (Lande 1988). Genetic analysis of Norwegian, Svalbard, and Russian arctic foxes using both nuclear DNA and mtDNA has revealed reduced genetic variation among the Norwegian foxes (Strand et al. 1998; Dalén et al. 2002). This is, however, not the same as detecting inbreeding depression. Until more data on the reproductive consequences of the loss of genetic variation in arctic foxes is available, it is not possible to conclude anything about the potential role of inbreeding in hindering population recovery, however given the minimal size of many populations it must be taken seriously.

8.2.2 Demographic collapse / Critical levels of population decline in a fragmented landscape.

In areas where cyclic populations of lemmings occur, arctic fox population dynamics are characterised by a high between-year variation in reproduction (Macpherson 1969, Angerbjörn et al. 1995, Tannerfeldt 1997). Arctic foxes have very high litter sizes in these areas (Tannerfeldt and Angerbjörn 1998). However, enough individuals must survive the years with low lemming availability to be able to mate and take advantage of the increase phase of the lemming cycle. Arctic fox generation length is identical to the period of lemming cycles in Scandinavia (4 years). A consequence is that a population is very sensitive to small changes in adult survival. If model parameters are correct, a 20% change in adult survival could mean a 70% change in the probability of extinction within 50 years (Loison et al. 2001). In other words, individual arctic fox populations are always exposed to a high risk of extinction.

In this context the immigration of a few individuals into a population during a cycle would allow the replacement of any adults that die and could have a very large stabilising effect on the population's dynamics. Studies of lemming population dynamics have often shown that there can be a degree of spatial asynchrony in cycles over all distance scales from 500m to 50-200 km (Myrberget 1973, Högstedt et al. 1991, Framstad and Stenseth 1993, Pitelka and Batzli 1993, Stenseth and Ims 1993, Krebs et al. 1995, Potapov 1997, Strand et al. 1998; Angerbjörn et al. 2001). As arctic foxes have been demonstrated to have a high dispersal capacity (Eberhardt and Hanson 1978, Garrott and Eberhardt 1987, Tannerfeldt and Angerbjörn 1996, Strand et al. 1998, Fuglei et al. 1998) it is likely that the immigration of individuals (born in an out-of-synchrony area) during the low, or increase, phases of a cycle has the potential to have a very strong stabilising effect. In effect, arctic fox populations may be dependent on a meta-population like structure where the sub-populations are units (territories, plateaux, mountain ranges) that are out of synchrony.

By the 1930's, the arctic fox population was reduced to a series of small and very isolated sub-populations. As several of the smaller populations became extinct this fragmentation became even more extreme. This effectively removed the stabilising influence of immigration, leaving the surviving relict populations exposed to allee effects and a high risk of local extinction (Fowler and Baker 1991, Hopper and Roush 1993). One example of an allee effect observed among radio-collared arctic foxes in Snøhetta was that after one member of a pair died, the survivor failed to find a new mate.

In effect the turn of the century (1800 - 1900) over-harvest reduced the population to a level below a critical size and degree of connectivity, so that it is in a form of "demographic trap", analogous to a predator pit except that allee effects replace the role of predation. Therefore for want of a better expression we call it the "demographic trap" hypothesis. With this background it is surprising that the relict populations have been able to persist for as long as they have. This hypothesis also allows for all of the above mentioned negative factors (climate, red foxes etc) to have a role in preventing an increase in the arctic fox population.

8.3 Consensus?

At present there is not enough evidence to separate between the competing hypotheses, and given the small size of the remnant populations it is difficult to imagine a study design that would be practical to conclusively separate between them. Furthermore, it is likely that it is a combination of factors acting at the same time, possibly with different relative importance in different areas. The consensus emerging at present among researchers and wildlife managers is that the competition from red foxes and demographic collapse hypotheses seem to be the most likely. Our view is that the population is at such a critical stage that it is important to initiate conservation actions at once, in the hope that they work and that we can gain further insights into the non-recovery process along the way – in effect this implies adopting a form of adaptive management.

9 Potential conservation actions

Despite the wide range of hypotheses that have emerged to explain the non-recovery of the Fennoscandian arctic foxes, there are in fact only a limited range of conservation actions that can be taken. These include (1) Supplementary feeding to increase survival and reproduction, (2) Red fox control to reduce competition and intraguild interactions, and (3) Population supplementation / reintroduction to restore connectivity and reduce the risks of allee effects and inbreeding depression.

In Sweden and Finland there have been attempts to conduct widespread red fox control and supplementary feeding in the period 1998-2002 and again from 2003-2007 under an EU financed LIFE project. The Norwegian government is also initiating such activities in Norway. Existing experience is not yet sufficient to conclude if these actions are effective in reversing the long term decline of arctic foxes. In addition, there are potentially some problems associated with the application of these methods (Linnell et al. 1999). Although they might potentially increase the density of local populations, it is unlikely that they will be sufficient to restore fox populations in areas where they have become extinct or restore the reduced genetic diversity of isolated populations. It is against this background that the idea of a population supplementation / reintroduction project CBSR (Linnell & Strand 1998; Linnell et al. 1999) was proposed in 1998.

10 Population supplementation / reintroduction project: a proposal

Embarking on a captive breeding and reintroduction project is not to be taken lightly as it requires a high level of funding over many years. However, given the critical stage at which the Fennoscandian arctic fox population is at, it seems fair to attempt all methods that are available. It was therefore considered important to attempt a reintroduction / supplementation project to selected areas. The advantages of this methodology over supplementary feeding / red fox control are that it (1) directly increases the numbers of foxes in a given area, (2) overcomes any potential inbreeding problems by maximising the remaining genetic variation in Norway, (3) can actually restore populations to areas where arctic foxes have become extinct or declined to levels where natural recovery (even with supplementary feeding and red fox control) is not possible. There are also disadvantages, namely that (1) it takes time to establish methods and build a large enough captive population, and (2) it has proven to be a very controversial project with the public.

We envision this project to have two phases. The first phase will be used to overcome technical difficulties and determine if the method is practical. At this stage it will be a small scale operation, using a limited number of founding animals and concentrating in a limited number of release sites . If this phase concludes that the method has potential, it can then move into a large scale phase 2 where the focus is on producing larger numbers of pups and releasing in multiple sites.

10.1 Why is captive-breeding necessary?

Many studies have demonstrated that the translocation of wild caught individuals from a healthy population is an effective way of supplementing a threatened population or of reintroducing a species back to an area from which it has vanished (Stanley Price 1989, Slough 1994, Smith & Clark 1994, Servheen et al. 1995). Despite problems of post-release movements and homing behaviour (Davis 1983, Slough 1989, Linnell et al. 1997), translocated carnivores generally have high survival (Fritts et al. 1985, Carbyn et al. 1994, Sjöåsen 1996). Translocation is generally to be preferred over the use of captive-bred animals (Stanley Price 1989).

However, there are no suitable sources of wild arctic foxes for translocation. None of the relict populations in Fennoscandia is large enough to be able to act as a donor of significant numbers of adult foxes. Genetic studies have revealed a clear difference between the foxes of the Scandinavian peninsula and those from the closest large populations on Svalbard, and the Kola and Taimyr regions of Siberia (Strand et al. 1998; Falén et al. 2002). In addition rabies is present in all these other populations (Prestrud 1992, Prestrud et al. 1992; Mørk & Presturd 2001; Griffith & Scott 1993), while Norway and Sweden are rabies-free.

10.2 Captive breeding – potential sources

Although animals from captive-breeding are not the best option, they have been used successfully in many situations for many species (Ginsberg 1994; Jefferies et al. 1986, Phillips & Parker 1988, Stanley Price 1989, Kleiman 1989, Beck et al. 1994, Carbyn et al. 1994, Soderquist & Serena 1994, Phillips et al. 1995, Kleiman 1996). At the start of this project there were no disease-free captive arctic foxes of wild origin in any zoos in Fennoscandia, implying that founding animals would need to be taken from the remnant wild populations. Although the remnant populations are critically small (see above), the natural mortality of arctic fox pups is very high (Garrott & Eberhardt 1982; Tannerfeldt & Angerbjörn 1996; Loison et al. 2001). Therefore, removing a small number of pups from wherever reproduction occurs in Norway should have a minimal effect on the donor populations.

We have developed protocols whereby we propose to take maximum 1 pup from small litters (3 or more pups) and take 2 pups from larger litters (5 or more). The ambition is to take pups as close to weaning as possible. This should increase the possibilities of taming the animals and adapting them to captivity as well as increasing the benefit of reduced intra-litter competition for remaining siblings. In cases where 2 pups are taken they should be of opposite sex, and wherever possible the smallest pups should be captured.

10.3 Captive breeding – methods

Arctic foxes have frequently been kept in captivity for experimental purposes (Rudzinski et al. 1982, Wakely & Mallory 1988, Kullberg & Angerbjörn 1992, Frafjord 1993, 1994) and for the purposes of commercial fur-farming. The domesticated form of the arctic fox, the blue fox, is common in fox-farms throughout Fennoscandia. Because of the wealth of experience that exists within the industry (Farstad et al. 1992, Farstad 1993, Farstad et al. 1993, Valberg 1993, Pedersen & Jeppesen 1990, Pedersen 1991, Moe 1996), and the ease with which large numbers of individuals can be maintained our initial plan has been to try and captive-breed the wild foxes in a conventional farm situation. This consists of raised netting cages, exposed to elements on all sides except for the roof. Apart from the low cost and practicality of these methods, there is the additional advantage that animals have a reduced risk of infection being raised above the ground. An earlier attempt to captive-breed wild caught arctic foxes in Sweden failed because of disease. While the exact nature of this disease has not been identified, it has been speculated that it could be transmitted through contact with the ground – the foxes were kept in enclosures with natural vegetation in the zoos. An additional advantage of this form of husbandry is that it allows ease of handling for health inspection and for the use of artificial insemination.

However, stress is a well known problem in farmed foxes. Despite extensive research into enclosure design and handling protocols it cannot be eliminated, even from the domesticated animals. It is therefore expected that wild-caught animals will be even more vulnerable to stress. An alternative captive-breeding scenario is therefore to keep foxes in larger enclosures (min 20 x 30 m) in natural high alpine habitat. This form of breeding will be more costly and has the above-mentioned risk of infection that needs to be accounted for (for example by having extra sets of enclosures allowing enclosure shifts and quarantine periods).

As there is very little experience with breeding wild-caught arctic foxes in captivity this part of the project will be associated with a degree of trial and error and may take some years to develop the methods that function best.

It is not intended that the original founding animals ever be released again, so these will be subject to careful handling in an attempt to make them as tame as possible. When it comes to mating it is intended to minimise inbreeding by mixing animals from different populations of Norwegian origin. While this will mean loosing any possible local genetic adaptation, the size of the remnant populations is too small to achieve a broad enough genetic base for conserving local populations. Hopefully between 15 and 20 breeding females could be used initially. This should allow the production of between 75 - 100 pups each year, most of which should be available for release.

10.4 Release methods

10.4.1 Pre-release training.

Following the experience of successful swift fox (*Vulpes velox*) reintroduction project in Canada we would plan to release captive-bred pups at the age of about 3 months in August (Carbyn et al. 1994). By releasing them at this age we; (1) simulate the natural age of dispersal, (2) minimise costs involved in holding large numbers of pups in captivity, (3) minimise the degree of habituation to humans, (4) duplicate the age at which they would learn to hunt for themselves in the wild, and (5) time release to correspond to a period of widespread carrion availability from the reindeer harvest (if released in South-Norway).

However, before release we would keep them in a larger arena for about a month after weaning to provide some anti-predator and hunting training (Miller et al. 1990a,b, Box 1991, Miller et al. 1994). Anti-predator training could include providing a mild-negative stimuli in association with an overflying raptor-shape and an approaching stuffed red fox and / or a domestic dog (Miller et al. 1990b, McLean et al. 1996). Ideally hunting training would include exposure to live rodent and bird prey, however if permission is not granted simulated lemming sounds and recently killed rodents could be used. The objective would be to expose them to all natural prey species and carrion.

All pups would be vaccinated against as many canid diseases as possible before release. Only individuals passing a veterinary inspection would be released to reduce the risks of disease transfer (Griffith and Scott 1993). The result of this preparation would be pups with the best behavioural and physiological conditioning available before they must face the alpine environment.

10.4.2 Release site assessment.

Using the available data on arctic fox ecology, former den availability and habitat distribution we would use GIS to plan the releases in the area where we feel that arctic foxes have the best chance of recolonising. The area of continuous habitat, connectivity to other alpine areas, number of former arctic fox dens and the presence of a relict population are all factors that need to be considered. Funding, costs and logistics will also feature in the evaluation process.

10.4.3 Release.

In the first phase of the project it will be necessary to conduct a soft-release, where foxes are kept in a large pen in the release area for a period of weeks before being released. Food will be provided in the release pen even after release so that the pups can adapt gradually to the wild. Soft-releasing should improve short-term survival and reduce post-release movements (Carbyn et al. 1994; Bangs & Fritts 1996; Linnell et al. 1997). Focused lethal control of any red foxes in the release site area may also be necessary. This form of intensive soft-release will be necessary in the initial stages to gain public support. However, with time it will be desirable to also attempt a hard-release strategy. Swift fox experience indicates that although this is associated with greater short term mortality – the long term result is the same as for soft-release (Carbyn et al. 1994). Throughout the development of the project we will lean heavily on experience from the swift fox project as it is the closest species to the arctic fox for which reintroduction experience exists.

10.4.4 Post-release monitoring.

All released foxes will carry an expandable radio-collar with a mortality option and a battery that should last for 1 year. This will allow us to follow the post-release movements, settlement behaviour and survival of the released pups. Apart from allowing us to monitor the success of the project, the ability to determine the causes of mortality of the released pups will help to understand the processes affecting arctic foxes in the alpine environment and to take steps to reduce this mortality. Additional feeding (a reindeer carcass) will be provided during the autumn and winter if it appears that a pup is experiencing difficulties in obtaining food. An effort will be made to recapture those pups surviving until late winter so that they can be equipped with a fixed radio-collar with a 2 year battery (i.e. Landa et al. 1998) Recapture will also allow for a monitoring of growth and body condition. Pups that are eventually born to released animals will be captured and radio-collared. This will allow the contribution that the released animals make to the population to be determined.

The annual monitoring of dens throughout the release area and other control areas must be continued as usual to allow changes in population development to be detected. In addition an effort will be made to radio-collar any wild foxes belonging to the relict population in the area to monitor the effect of the release on their behaviour.

Contingency plans will be made for possible problems that might arise after release. These include cases of scabies, or signs that some individuals are having difficulty in obtaining enough food. As the main goal of the restoration experiment is to test the effect of increasing the number of foxes, a relatively high degree of intervention in individual cases should not cause problems.

10.4.5 Defining success.

It is important to define criteria for accepting the success of any such experimental restoration program, although this can often present many problems (Ralls et al. 1996). Long term success of the restoration can only be defined by the re-establishment of a viable population of arctic foxes within the release area. However, we need to define some short term criteria to evaluate the experiment as it progresses. Precise definition of these criteria will require further development, but some guidelines will include;

(1) Survival. Mortality of wild arctic fox pups in Scandinavia is very high during the first year of life, in cases it may reach 70-90% (Tannerfeldt & Angerbjörn 1996). Therefore we must expect high mortality also in the released captive bred pups rates (Carbyn et al. 1994). However, by the time that individuals have reached 1-year of age it can be expected that most surviving individuals will have adapted to the wild situation (Carbyn et al. 1994). At this stage we expect that the released individuals will have a survival rate similar to that expected for wild individuals.

(2) Pair formation. A prerequisite for population growth is that the released individuals form reproductive pairs, occupy a den and establish a territory. This adoption of wild behaviour will also be used as a criteria for success.

(3) Population growth. Once released animals have reached reproductive age we would predict that within the period of a lemming cycle (about 4 years) that the new expanded population will at least be able to maintain itself through reproduction.

10.5 Co-operation

Such an ambitious project cannot be achieved by one institute alone. In terms of captive-breeding we have established an advisory group with representatives from the various veterinary environments in Norway (including those working with farm foxes), ecologists working on high alpine ecology and arctic fox (University of Tromsø, and University of Stockholm (SEFALO+). It is also established cooperation with Langedrag zoo. In many areas we will have to look beyond Norway's borders to cooperate with colleagues in Sweden and Finland. We aim to standardize our monitoring methodology and reporting systems to make cross-border comparisons easier. The inclusion of Norway in the SEFALO+ project financed by the EU-LIFE program focuses on this monitoring cooperation. Access to good quality monitoring data is a prerequisite for evaluating the success of any recovery projects.

It is especially when it comes to testing different management actions in the field that we will have to look for cooperation with Sweden and Finland. Irrespective of the cause of arctic fox non-recovery there are a limited number of management options that are available. The SEFALO (1998-2002) and SEFALO+ (2003-2007) projects are testing the potential for supplementary feeding and red fox control in Sweden and Finland. Captive-breeding and reintroduction is the other main approach that we have focused on in Norway. Testing any of these methods in the field is expensive and resource demanding. In order to get the most out of our efforts we will work with our colleagues in Sweden and Finland to adopt an integrated Fennoscandian approach. Meanwhile, the development of captive-breeding and release activity will be concentrated on south Norway where results will be easy to monitor, and where there is no difficulty in separating the impact of these actions from those ongoing in Sweden / Finland. As a result of this integrated approach of science and field testing management actions we will be able to pool our experience to determine which actions are most successful under which conditions. At this point, when the field experience has been evaluated and the present package of research is complete, it should be possible to come up with a consolidated plan for the entire Fennoscandian region.

10.5 Progress 2000-2004

The project received official approval in spring 2000. However, in summer 2000 there were no documented reproductions among wild arctic foxes in Norway. In summer 2001 a total of 6 pups were caught, followed by 3 more in 2002. These represented at least 4 of the extant populations (Hardangervidda, Børgefjell, Saltfjellet and Finnmark). All animals were housed in a conventional farm situation at Dal forsøksgård (Dal experimental animal station) belonging to the Norwegian Veterinary University until early 2004.

In the breeding season of 2002 when the first group of founders were 10 months old no heat was documented in the females, although all males had motile sperm. In the 2003 breeding season, again no heat was documented in the females (3 of which were now 20 months old). It is unknown if this failure to enter oestrus is an artefact of being held in captivity or if it represents the natural age of first reproduction in Fennoscandian arctic foxes. During this period one individual died of uncertain causes. For the 2004 breeding a wide range of methods have been introduced to try and reduce stress in the farm situation, as well as moving the most stressed individual together with his chosen mate to a natural enclosure setting at Landedrag zoo, and moving another pair to another fox farm where they could receive intensive habituation. Unfortunately, one of the pair moved to the second fox farm died prior to the mating season in April, 2004. Plans for a set-up with large enclosures in a natural habitat is currently under development and will be carried out if the conventional farm set-ups fails to produce pups during 2004 and if financial support could be raised. At present this leaves us with 7 foxes – 4 males and 3 females.

Monitoring of the remnant populations continues and GIS based release site assessment based on this monitoring data is being conducted – to be completed during 2004.

11 Have we fulfilled the criteria for a successful supplementation / reintroduction project?

Various authors have published reviews of the criteria that need to be met for a successful reintroduction / supplementation project to be a success (Kleiman 1989, 1996, Stanley Price 1989). By way of summarising this action plan we will now examine our proposal in light of 10 points listed by Kleiman (1996) as vital for evaluating such a proposal.

A. The reasons for the reduction in species numbers have been eliminated.

Over-harvest was clearly the original reason for arctic fox decline. As they are now protected from hunting and trapping the reason for decline is completely removed. Arctic foxes generally have a good public image and there is unlikely to be much illegal killing. Although the reason(s) for non-recovery are not totally clear, we are at a stage where inaction will lead to regional extinctions. Furthermore, despite the wide range of hypotheses for non-recovery, the number of potential conservation actions is finite, and all are being tested at present. The hope is that we will learn from the activity. It is felt that we must act now, even in the face of incomplete knowledge, and learn from the process (Sarrazin & Barbault 1996).

B. Sufficient habitat is protected and secure.

Large areas of alpine habitat remain throughout Norway and Fennoscandia as a whole, both inside and outside national parks. Generally, these habitats are in good condition, all of the original prey species and all of the original small and medium sized predators are present (Gjershaug et al. 1994). The only exception is the absence of the larger predators and the uncertainties of the lemming cycle (see above). The significance of their absence is hard to quantify. Land use patterns in all alpine areas consist of sheep grazing, semi domestic reindeer, hunting for wild reindeer and ptarmigan, fishing and foot tourism. These activities should generally be compatible with arctic fox recovery, especially as the present trend is for management to regulate human activity to an even greater extent.

C. Available habitat exists with low densities of, or without, native animals.

Arctic foxes are absent from much of their former range in Norway. Even in areas where relict populations of arctic foxes occur, there are many 10's or 100's of empty dens available.

D. It is certain that the release of animals will not jeopardise the existing wild population.

Due to the amount of unoccupied habitat the release of captive born pups should not have any negative effects on the relict populations through competition. As all captive-born pups will have health controls and vaccinations against common diseases there should be no medical problems either (Griffith & Scott 1993).

E. Sufficient information exists about the species' biology in the wild to evaluate whether the program is a success.

Enough background monitoring and data on ecology of the target populations exists to be able to determine if the situation of the population has improved following the restoration attempt. Monitoring of other relict populations will continue as a control. Monitoring in Norway is coordinated as part of a national monitoring program.

F. Conservation education exists.

The Norwegian public are aware of broad environmental issues, although they have been unaware of the seriousness of the plight of the arctic fox until recently. We shall use this opportunity to educate the public about the problems facing the arctic fox and the alpine environment as a whole. The mass media have expressed an interest in the status of the arctic fox, and political support at the highest level has been secured for arctic fox conservation. Several internet pages provide information.

G. The population in captivity is secure, well managed, and has surplus animals.

No self-replacing captive population exists at present. The wild animals that are being captured are mainly being captured to initiate this program. Animals will only be released when a surplus in captivity is available.

H. Knowledge of the techniques of reintroduction exists.

The primary author of this report is a member of the IUCN Reintroduction Specialist Group. In addition, a reference group has been established for the project (see Appendix 2). We shall work closely with veterinary, wildlife managers and zoo specialists at all stages of the project. Contact has been initiated with the swift fox reintroduction project in Canada and the Cochrane Ecological Institute, which together have run one of the most successful canid reintroduction projects yet (Carbyn et al. 1994).

I. Resources for post-release monitoring are available.

A prerequisite for beginning this project is that funding needs to be guaranteed to see it through to the end. The situation of the arctic fox has attracted a great deal of political support and there is currently adequate funding for monitoring (organised in a National Monitoring Program), research and the initiation of recovery activities.

J. There is a need to augment the size / genetic diversity of the wild population.

Based on our current monitoring data and status estimates we feel that without supplementation of the relict populations, arctic foxes are at a high risk of becoming extinct in Norway within a short time period. The demographic collapse and inbreeding hypotheses predict that restoration of more continuous populations will lead to a restoration of a meta-population like structure, which will allow population growth. Therefore we believe that an attempt at restoration, through augmentation, is crucial.

12 The consequences of doing nothing

Arctic foxes have been protected for 74 years (since 1930) in Norway, 76 years in Sweden (since 1928) and for 65 years (since 1940) in Finland. During these periods none of the arctic fox populations have recovered to anything like their former levels. Instead they have vanished from many alpine plateaux where they previously occurred, and in general appear to be on the edge of regional extinction. Obviously there are many risks associated with having all individuals associated with a few small populations. For example, canid populations are vulnerable to disease like scabies, distemper, rabies and ear mites (Macdonald 1980, Brand et al. 1995, Goltsman et al. 1996). Disease may have strong effects on small carnivore populations - distemper being responsible for the extinction of black-footed ferrets *(Mustela nigripes)* in the wild, and ear mite infestation greatly reducing the arctic fox population of Mednyi island (Clark 1994, Goltsman et al. 1996). The possibility of transmission of disease from wild red foxes, escaped farm arctic foxes and red foxes, or domestic dogs will always be present. Also, single, isolated populations are vulnerable to the entire range of stochastic environmental effects that could result in local extinction.

The implications are that the consequences of inaction are likely to be national (and probably regional) extinction.

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Appendix 2. Reference group for captive breeding – reintroduction project

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Jan Fougner, Norwegian Fur Farmers Association, Oslo, Norway (health)
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