Afuture for arctic foxes in Norway?

A status report and action plan

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Overvåking av fjellområder og ynglehi mellom 1988 og 1998 har vist at fjellreven er funksjonelt utryddet fra mange av de undersøkte fjellområdene. Små og isolerte restbestander finnes fortsatt i sju av de undersøkte områdene (Hardangervidda/Nordfjella, Snøhetta, Tydalen/Holtålen, Sylane, Børgefjell, Saltfjellet og Dividalen) samt noen spredte forekomster i Finnmark. Med unntak av Børgefjell, har vi ikke med sikkerhet kunnet dokumentere mer enn tre reproduksjoner i noe år i noen av disse områdene. I Børgefjell har vi på det meste sett seks ynglinger i løpet av ett år på Norsk side av riksgrensen. Det er en klar tendens til at de fjellområdene hvor vi fortsatt finner fjellrev også er de største områdene. Samtlige av de undersøkte bestandene må kunne karakteriseres å ha en høy risiko for utdøing. Basert på innsamlede data har vi estimert at det neppe er mer enn 50 voksne fjellrever i Norge. Med bakgrunn i det som er kjent omkring fjellrevens økologi og bestandsdynamikk, tilbakeviser vi tidligere framtredende forklaringer på at fjellreven ikke har økt i antall etter fredningen som ble innført i 1930 og lanserer en ny hypotese som vi kaller for en ”demografisk felle”. Denne hypotesen er basert på en analyse av fjellrevens livshistorie og populasjonsdynamikk i et miljø som har sykliske byttedyrvariasjoner. Vi foreslår at mangelen på vekst i fjellrevbestandene skyldes det høye jakttrykket ved starten av dette århundret, som medførte at både **tettheten** og **sammenhengen** i fjellrevbestandene ble ført under en terskel som på sikt medfører lokal utdøing. Dersom denne hypotesen holder stikk, betyr dette at verken en antatt nedgang i fjellrevens samlete byttedyrtilgang, eller konkurranse med rødrev, alene kan bidra til å forklare utviklingen i fjellrevbestanden.

Vi anbefaler at overvåking og forskning på de gjenværende bestandene skal fortsette, og at det bør utarbeides spesielle forvaltningsplaner for de siste bestandene av nevneverdig størrelse i Børgefjell og Hardangervidda/Nordfjella. Vi tilbakeviser tilleggsfôring og utsetting av fjellrev fra Russland eller Svalbard som mulige forvaltningsstrategier. For å kunne reetablere fjellrev, samt å beskytte de gjenværende restbestandene, foreslår vi at et opplegg for innfanging, oppdrett og utsetting av fjellrev bør prøves. Fortrinnsvis bør dette være hvalper som er født i områder i Norge hvor det kan påvises reproduksjon. Vi antar at en reell vekst i fjellrevbestanden vil kunne oppnås dersom utsetting av fjellrev lokalt bidrar til å gjenskape den naturlige rommelige og temporære dynamikken. Vi skisserer et program som har til hensikt å teste ”demografisk felle” hypotesen. En slik test kan eventuelt senere danne grunnlag for et framtidig restaureringsprosjekt.

Emneord: Fjellrev - Alopex lagopus – overvåking – status – sårbarhet – utdøing - forvaltningsplan

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Abstract

A future for arctic foxes in Norway? A status report and action plan. Linnell, J.D.C., Strand, O., Loison, A., Solberg, E.J. & Jordhøy, P. 1999. - NINA Oppdragsmelding 576: 1-34.

Surveys of mountain areas and dens between 1988 and 1998 have revealed that arctic foxes are functionally extinct in many mountain areas. Small, remnant populations remain in seven discrete mountain areas (Hardangervidda/Nordfjella, Snøhetta, Tydalen/Holtålen, Sylane, Børgefjell, Saltfjellet, Dividalen) and scattered across Finnmark. Apart from in Børgefjell, no more than two reproductions have been observed in any one year in these areas. The most observed in Børgefjell in one year has been six on the Norwegian side. A clear pattern exists for arctic foxes to have persisted on the larger mountain areas. All of these populations must be categorised as being under very high risks of local extinction. Based on this data we estimate that there are no more than 50 adult arctic foxes in Norway. We reject most of the conventional hypotheses that have been used to explain the non-recovery of arctic foxes and propose a new one called the “demographic-trap” hypothesis. This is based on an analysis of arctic fox life history and population dynamics in an environment with cyclic prey, and proposes that non-recovery is due to the populations having been reduced (through turn of the century over-harvest) to below critical levels of both *density* and *connectivity* so that local extinction is more or less inevitable. This implies that neither a putative decline in prey availability or competition with red foxes is ultimately to blame for non-recovery.

We recommend that monitoring and research of the relict populations should continue, and that special management plans for the last sizeable populations on Børgefjell and Hardangervidda/Nordfjella should be established. We reject supplementary feeding and translocation of Russian or Svalbard foxes as viable conservation strategies. In order to restore arctic fox populations to a viable status in the mountain plateaux of south Norway we propose a captive-breeding and release program. The source animals would be wild born pups from wherever in Norway reproduction occurs. We predict that population growth will begin if the population can be augmented to a level where the natural spatial and temporal dynamics are restored. This program will firstly be an experimental test of the “demographic-trap” hypothesis for population non-recovery, and secondly a conservation orientated, restoration project.

Key word: Arctic fox - Alopex lagopus – monitoring – status – vulnerability – extinction - management

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Foreword

Various parts of our work on arctic foxes during the last ten years have been funded by the Directorate for Nature Management, the Norwegian Institute for Nature Research, the Norwegian Research Council and the County Govenor's departments of environmental affairs from Nordland, Nord-Trøndelag, Sør-Trøndelag, Telemark, Buskerud and Hordaland counties. Discussions with Karl Frafjord, Anders Angerbjörn, Magnus Tannerfeldt, Påll Prestrud, Nina Eide, Påll Hersteinsson, Jon Swenson, Arild Landa and Ludvig Carbyn have helped form our ideas of how arctic fox populations function, or in this case, fail to function. We are grateful to the following for their invaluable field work in checking dens, reporting observations and providing data; Sigmund Holte, Svein Vetle Trae (Brattefjell-Vindeggen), Sverre Tveiten, H. Bitustøyl, S. Rabbe, K Hallingstad, K. Solaas, M. Hallanger, Bjørn Haugen, Knut Nylend, Harald Skjerdal (Hardangervidda/Nordfjella), Egil Soglo, Amund Byrløkken, Edgar Enge, Finn Sønsteby (Rondane), Lars Børve, B. Zimmerman, M. Dötterer, T. Bretten, B. Heidenreich, M. Heim, E. J. Solberg, Arild Landa (Snøhetta), Erik Ydse (Sølenkletten), Dag Bjerkestrand (Tolga Østfjell), Lars Olav Lund (Trollheimen), Ingebrikt Kirkvold (Tydalen-Holtålen), Hans Inge Lund Tangen (Meråker/ Blåfjell), Per Lorentsen, Øyvind Spjøtvoll, T. Grøveng, S. Trøen, L. Monsen (Børgefjell), Arne Graven (Saltfjellet), H. Bolstad, G. Øvergård, C. Grimstad, A. Olsrud (Dividalen), Jon Meli, K. Gullvik (Forelhogna), Erik Lund (Finnmark). Without the uncountable number of hours that these individuals have spent walking around the mountains looking at holes in the ground we would not be in the position where we can document just how serious the plight of the arctic fox actually is in Norway.

Contents

1 Introduction

The arctic fox (*Alopex lagopus*) populations of Fennoscandina 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 & Nilsson 1977, Østbye et al. 1978, Pedersen et al. 1986, Frafjord 1988, Hersteinsson et al. 1989, Angerbjörn et al. 1995, Kaikusalo and Angerbjörn 1995). However, there has been no review of the entire Norwegian situation since 1985 (Pedersen et al. 1986, Frafjord 1988), although Frafjord & Rofstad (1998) presented a summary for the Nordkalotten region from 1987-97, and the available information for Svalbard has been summarised by Fuglei et al. (1998). The first aim of this report is to summarise the existing data concerning the development of the arctic fox populations in Norway (especially south Norway) during this century, and to present new data collected since 1988 on distribution and reproduction of arctic foxes based on den inventories collected as part of NINA's Snøhetta alpine ecology project and the Directorate for Nature Management's Terrestrial Monitoring Program (TOV). The second aim is to outline options for management and research strategies that could lead to the recovery of arctic fox populations in south Norway.

2 Arctic fox distribution and status world-wide

Throughout their range arctic foxes are confined to tundra and alpine habitats, probably being excluded from more productive regions by interference competition with red foxes (*Vulpes vulpes*) (Hersteinsson & Macdonald 1992, Linnell et al. in press, Strand et al. 1998a). 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 & Eberhardt 1987, Ginsberg & Macdonald 1990).

In most regions arctic foxes are still commercially exploited for their furs, although they are now protected in Norway (not Svalbard), Sweden, Finland, and Iceland. Regulation of trapping is very limited, however, there are not any reports of serious population declines from areas where they are harvested (Ginsberg & Macdonald 1990). The total Holarctic harvest probably lies between 50 000 and 100 000 foxes each year (Banikov 1970, Ginsberg & 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 & Macdonald 1990), except for the major exception of Fennoscandia, where populations have been in a long term decline (Hersteinsson et al. 1989).

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 & 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 Dalsbyda municipality (Forelhogna) 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).

4 The original decline - pre1930

There is little doubt that it was direct persecution that 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. By the early 1920's the price paid for a fox skin equalled a labourers annual salary (Østbye & 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 that were aimed at other species like red fox or wolverine (Olstad 1945, Østbye et al. 1978).

5 Regional development 1930-1985

The data available to chart the development of arctic fox populations during the last 68 years 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 1**. 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 1a,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 1c**). The most recent data (**figure 1d**) 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 Population distribution and status 1988-98

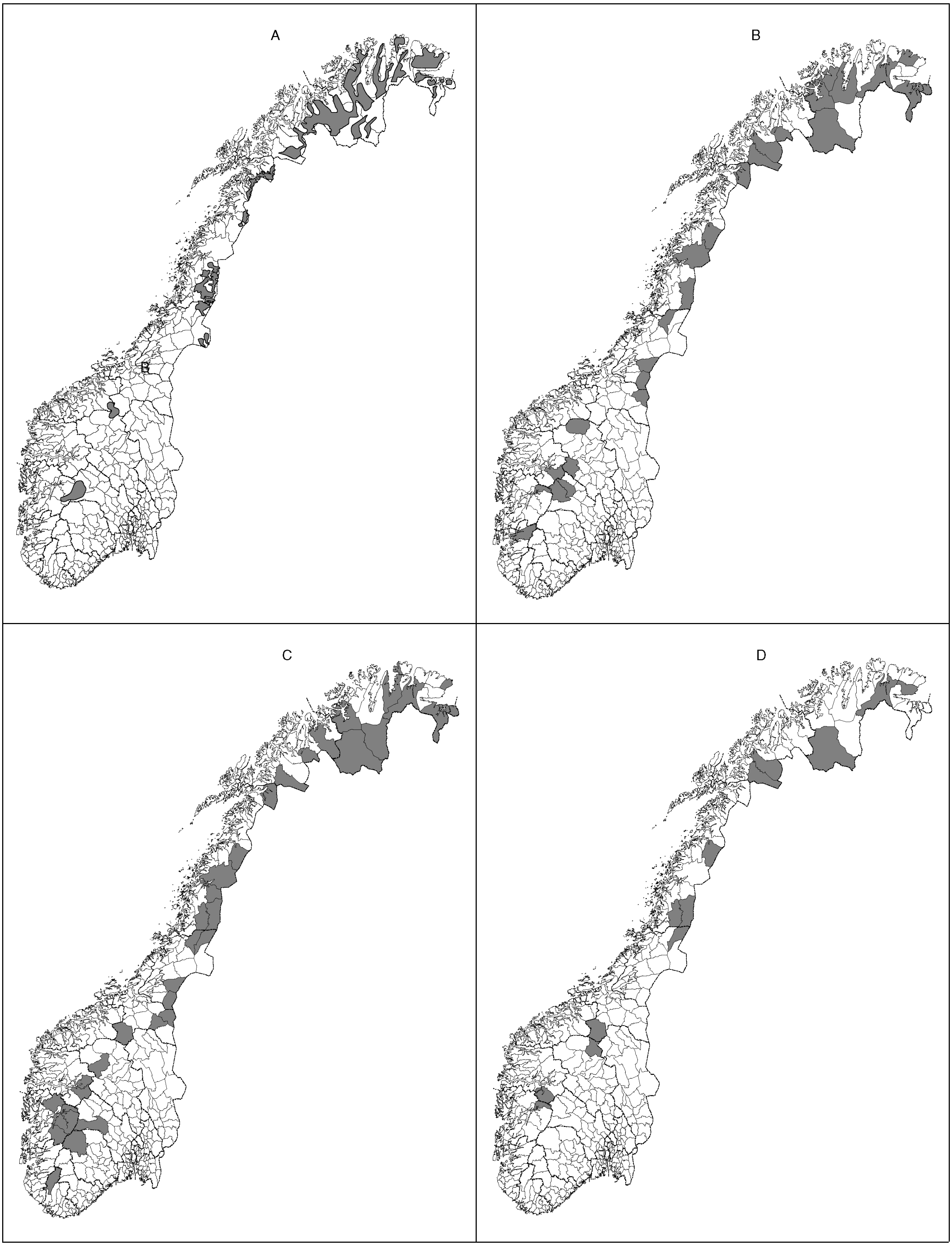
Data available to evaluate the recent status of arctic foxes come from various sources. A field research project was run by NINA in Snøhetta from 1988-1995. From 1993-1997 Hardangervidda, Snøhetta, Børgefjell and Dividalen were included in the Terrestrial Monitoring Program (TOV) (DN 1989, 1997) (**table 1**), with additional, but less regular, monitoring and surveys in Saltfjellet, Trollheimen, Forelhogna, Knutshø, Reinheimen, and Rondane. From 1998, arctic foxes were removed from the TOV program, but it has been possible to continue monitoring in Hardangervidda, Snøhetta and Børgefjell with funds from DN and the various county management offices. Some informal den visits have been made by various managers from the county environmental protection offices. Observations and 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 between 1987 and 1997.

6.1 Areas without regular monitoring

No systematic monitoring of dens has occurred in the following areas during the last 10 years (**table 2**). However, a winter survey was made of many sites in April 1995. This corresponds to the period when mated pairs begin clean out a den prior to mating and birth, so that their presence can be detected. In addition, we have contacted local mountain wardens asking for information. Therefore the data should be regarded as only an approximate overview. However, it seems unlikely that many reproductions will have been overlooked.

Setersdal/Ryfylkeheiene
Two former arctic fox dens are known in the area, but have not been regularly monitored. According to local contacts and mountain wardens there have been no reported reproductions in the area during the last decade, although there are occasional reports of single individuals being seen, the most recent of which was in 1992 during winter.

Brattefjell/Vindeggen
Three former arctic fox dens are known from the area, but there have been no recorded reproductions in recent decades. A winter survey in April 1995 located no signs



Figur 1 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 *This report.*

of activity and there have been no reports or observations.

Nordfjella

Observations of arctic foxes have been made within Nordfjella, on an annual basis for the last decade. Reproduction has been documented in the south-western portion as recently as August 1998. Given the low numbers of people travelling in the area, this relatively high number of observations gives reason to believe that there could be an unknown number of undetected reproductions occurring on an annual basis in the area. Unfortunately, the geology of the area has led to a low availability of large sand dens. Accordingly, arctic fox reproduction probably occurs in stone and bedrock dens, which are almost impossible to detect and monitor. Of all the areas which have not been regularly monitored, Nordfjella deserves the most attention in the future.

Reinheimen (Ottadalen)

Former arctic fox dens are known from the area, but there has been no confirmed reproduction during the last decade. Observations of individuals are common, with the most recent being in autumn 1997. It is possible that undetected reproductions may occur.

Rondane

Six former arctic fox dens are known from this area. Of these three dens have been monitored annually since 1986 without reproduction being observed. Reproduction was observed in one of the other dens in summer 1993. None of the six dens showed signs of activity in April 1995, although one single animal was seen. One radio-collared animal from Snøhetta crossed into Rondane in

Table 1 The number of former arctic fox dens checked, the number where recent activity was visible (in use) and the number where reproduction was confirmed, for arctic and red foxes for each year in the four different areas monitored in the TOV program. The asterix refers to years where reproduction occurred in a den that was not detected by the monitoring program. A "?" after reproduction implies that there was only indirect evidence (scats and digging) for the birth of arctic fox pups.

	Arctic fox			Red fox	
	Dens checked	**In use**	**Reproduction**	**In use**	**Reproduction**
Hardangervidda					
1993	13	1	0	0	0
1994	24	2	0 + 1*	0	0
1995	25	9	0	1	0
1996	32	1	0	1	0
1997	82	4	0 + 1*	11	9
1998	34	-	0 + 2*	-	6
Snøhetta					
1988	2	0	2	0	0
1989	2	0	2	0	0
1990	2	1	1	0	0
1991	3	2	1	0	0
1992	6	2	1	0	0
1993	7	5	1	0	0
1994	18	3	1	0	0
1995	18	10	0	1	0
1996	24	5	0	2	1
1997	18	5	1?	0	0
1998	23	2	1?	1	0
Børgefjell					
1993	20	0	6	0	0
1994	20	2	6	0	0
1995	18	6	2	0	1
1996	23	2	1	0	0
1997	24	2	1	0	0
1998			3		
Dividalen					
1991	8	2	3	0	0
1992	10	6	0	0	0
1994	13	3	1	0	0
1995	16	3	0	2	0
1996	16	0	1	2	0
1997	13	3	1	0	1

1993, but later returned. Arctic foxes were reported as being seen as recently as August 1998.

Knutshø
Seventeen former arctic fox dens are known from this region. There has been no reported reproduction by arctic foxes here for at least the last decade. However, there have been some sightings of single animals, and radio-collared animals from the neighbouring Snøhetta area have visited the area briefly.

Sølenkletten
Three former dens are known in this area. No reproduction or activity has been observed during recent years.

Trollheimen
Three former arctic fox dens are known from this area. During a winter survey in April 1995 there was no sign of activity at these dens. There has been no documented reproduction in this area during recent decades, although a few occasional observations of single animals have been reported.

Forelhogna
A total of 24 former dens are known in this area. There has been no documented reproduction or use of dens by arctic foxes since the 1960's. Single animals are occasionally seen, most recently in 1989.

Sylane
Reproduction has been constantly documented since the 1980's (Frafjord 1988). Activity was registered at two dens in April 1995. Local contacts report 2-3 dens being in regular use on the Norwegian side of the border. Although production was reported on the Swedish side of the border in 1997, there were no signs of production on the Norwegian side. Only one of three dens showed signs of any activity.

Tydalen-Holtålen
Three former arctic fox dens were checked in April 1995, and two showed some signs of use by arctic foxes. In summer 1997, two dens showed signs of activity, but there was no evidence of pup production, and two appeared to be unused.

Meråker/Blåfjell
Several former dens are known (10-20), but there has been no reported activity in any since the 1960's.

Saltfjellet
Seven former arctic fox dens are known and have been regularly monitored from this area. Activity has been recorded in two of these, with evidence of reproduction in one of these in 1994 and in both in 1995. Activity was also reported in 1996. A number of additional dens have been checked by Frafjord & Rofstad (1998) in the same region (Saltfjellet/Svartisen), where a few extra reproductions have occurred during the last 10 years.

Troms, outside Dividalen
A total of 10 dens are known outside Dividalen (see next section). Reproduction has been observed in one of these (in Storfjord municipality) in 1997 (Frafjord & Rofstad 1998).

Table 2 The status of arctic foxes in the various mountain areas of Norway 1988-97. For each area the status is given, along with the date of last known reproduction, the maximum number of reproductions recorded in any one year after 1988, the total number of individual dens where reproduction has been documented during the monitoring period, and two estimates of minimum population size.

Area	Status	Last known Breeding	Maximum breeding	Total dens	Minimum population
Setersdal/Ryfylkeheiene	***Extirpated + sightings***	-	0		
Brattefjell/Vindeggen	***Extirpated***	-	0		
Nordfjella	***Remnant population ?***	1998	1-1998		2.5/2.5
Sognefjell	***Extirpated + sightings***				
Jotunheimen/Jostedalsbreen	***No data***	-			
Reinheimen (Ottadalen)	***Regular sightings***	-	0		
Rondane	***Occasional reproduction***	1993	1 - 1993	1	2.5/2.5
Sølenkletten	***Extirpated***	-	0		
Trollheimen	Extirpated + sightings	-	0		
Knutshø	***Extirpated + sightings***		0		
Forelhogna	***Extirpated + sightings***	1967	0		
Sylane	***Remnant population***				
Tydalen-Holtålen	***Remnant population***				
Meråker/Blåfjell	***Extirpated***	-	0		
Saltfjellet	***Remnant population***	1995	2 - 1995	2	5/5
Finnmark.	***Remnant population***	1993	1 - 1993	3	2.5/7.5
Hardangervidda	***Remnant population***	1998	2 - 1998	1	5/5
Snøhetta	***Remnant population***	1997	2 - 1989	3	2.5/7.5
Børgefjell	***Remnant population***	1998	6 - 1994	11	15/27.5
Dividalen	***Remnant population***	1997	3 - 1991	5	7.5/12.5

Finnmark
A total of 38 dens have been occasionally checked in various areas of Finnmark between 1986 and 1997. Reproduction has been documented on five occasions, with the most recent case in 1997. It is likely that there are more undetected reproductions in Finnmark, and more intensive surveying would help to clarify the populations status. However, the fact that reproductive activity could only be detected in 3 of 37 dens is a very clear signal that the population is at a very low density.

Jotunheimen/Jostedalsbreen
There has been no surveying of these areas, however, we have not received any reports of reproduction. Based on our knowledge of arctic fox habitat preferences (Landa et al. 1998a) the very steep, rocky and high alpine habitats typical of this area are unlikely to be very suitable for arctic foxes. Reports of individual foxes being seen during winter have been made during the mid 1990's.

Sognefjell
Occasional observations of tracks and single individuals have been reported, although no former dens are known and no reproduction has been reported.

6.2 Areas with regular monitoring

In these areas, all known former arctic fox and red fox dens have been checked on a more or less annual basis for varying periods (Kålås et al. 1994, Kålås et al. 1995, Strand et al. 1996, Strand 1997, Strand 1998). While it is possible that some reproduction may occur outside these dens, we believe that these must be quite limited as much effort has been spent on visiting the areas and following up reports.

Hardangervidda
The numbers of dens monitored in Hardangervidda has increased steadily since the monitoring program began in 1993. The largest increase was in 1997 when we attempted to re-survey as many as possible of the 136 dens that were originally surveyed by Eivin Østbye and co-workers in the early 1970's. We were able to find a total of 46 of these dens again. Many others were either too eroded to recognise or were in areas where we did not have time to search. The 1997 survey (82 dens) was the most extensive snap-shot ever taken of the population. The availability of small rodents on which arctic fox reproduction depends was medium, but there were at least enough to support the reproduction of 11 families of red foxes. Despite these favourable conditions no arctic fox reproduction could be documented in the surveyed dens. However, there were reports of reproduction at another den close to Finse. Live-trapping during August revealed 3 adults and 7 pups. These were all radio-collared to aid in future monitoring.

Although arctic foxes appear to be still using some dens throughout Hardangervidda, there appears to have been no increase in numbers since the Østbye et al. surveys of the 1970's. If anything the population has declined even further. The absence of detectable arctic fox reproduction during the peak in small rodent abundance in 1994 is a strong indication of the absence of arctic foxes. There has been a definite decline since the 1930's when Sømme (1932), Høst (1935) and Olstad (1945) mention 2, 3 and 4 reproductions respectively in the central plateau between rv7 and the Lågen watershed. Our surveys have revealed extensive reproduction by red foxes in the area, but no indication of reproducing arctic foxes. It is only in the higher lying area around Finse that there has been any regularly documented reproduction since the 1970's (Østbye et al. 1978). Future surveys for extra dens should concentrate on the higher areas in western Hardangervidda, around Finse and Nordfjella.

Snøhetta
Arctic foxes on Snøhetta have been studied using dens surveys and radio-telemetry since 1988. Early work concentrated on two dens where reproduction was observed, however, the number of dens monitored increased continuously during the period. Despite this increase in the number of dens monitored, there has been a decline in the number of reproductions observed. It also seems unlikely that any pups survived to weaning from the 1994 and 1997 reproductive attempts. Similarly, among the radio-collared adults, there was no observed replacement of those that died, which led to a decline in the study population during the whole period. Based on these data, we can only document a single breeding pair in the mid 1990's. Even during 1998 when rodent numbers were at a medium level, monitoring could not document any pups surviving to weaning, although it is possible that there was a reproductive attempt in one den.

Børgefjell
Børgefjell appears to be the only area in Norway where a functioning arctic fox population of any size may still exist. Regular peaks of reproduction have been observed here each summer when small rodent abundance peaked, since the late 1970's. 1994 and 1998 were the most recent peak years, when at least six and three reproductions respectively were observed on the Norwegian side. Although small, the population at least appears stable at present (Strand et al. 1998e).

Dividalen
Reproduction has been observed regularly in the dens in Dividalen during the 1990's, although only about 1 or 2 reproductions can be documented in a good year.

7 Summary of status and minimum population size

Single observations of arctic foxes, or dens that have been recently used are hard to interpret, because they could be due to young individuals that are naturally wide ranging over 10's or 100's of square kilometres. The same individual may be responsible for many of the same observations, tracks or den use records. The use of such observations has already led to severe over-estimates of brown bear population density in Norway during the 1980's (Kolstad et al. 1986, Elgmork 1988, Swenson et al. 1995). There is also the risk of some of these observations being due to animals that have escaped from fox farms. Also, at very low population density, a single individual may not be able to find a mate, and does not therefore reflect the existence of potential reproductive units. Therefore, we shall only interpret the data based on confirmed reproductions, as these are unambiguous evidence for the existence of a functioning reproductive unit of at least a pair of adult arctic foxes.

We present two minimum population sizes. Firstly, as arctic fox reproduction is dependent on peaks in small rodent abundance (which may be out of sequence in different areas) we have used the year with most reproductions during the last seven years (time enough for each area to have experienced at least one peak) to calculate a minimum population size for each area. We allowed for the presence of a mated pair at each reproductive den, plus an additional adult animal ("helper") at half of these dens (Frafjord 1991, Strand et al. 1998b). Therefore we simply multiplied the maximum number of reproductions in any one year during the monitoring period by 2.5. The second method assumes that a den is occupied by a discrete family that do not change den during the study period (Strand et al. 1998b). Therefore we simply multiply the number of individual dens where reproduction has occurred at least once at some stage during the monitoring period by 2.5. This method could only be used for the areas where regular monitoring data from dens is available.

Based on the data available (**table 3**) there are at least 7 discrete remnant populations which have persisted at least up until the 1990's (Hardangervidda-Nordfjella, Snøhetta, Tydalen-Holtålen, Sylane, Børgefjell, Saltfjellet, Dividalen) plus scattered reproductive events across Finnmark. It appears that arctic foxes are absent from at least 8 other areas. However, with the exception of Børgefjell there have not been more than 3 reproductive events in any population in any given year. In each area, the vast majority of dens have been documented as being not in use. The result is that all of these remnant populations are at critically low levels. Even in Børgefjell there were only a maximum of six reproductions in two years, in 1993 and 1994. This allows for between 15 and 27 adults on the Norwegian side of the border. The result is that there may have been around 40-53 adult arctic foxes (including helpers) engaged in reproduction in the areas that we have surveyed in Norway during the last 10 years. These have been scattered between Hardangervidda in the south and Tana in Finnmark in the north, a distance of 1400 km.

It should be noted that the Sylane, Børgefjell, Saltfjellet and Dividalen populations border onto mountain areas in Sweden where arctic foxes exist (Frafjord & Rofstad 1998). However, the populations in Sweden are also estimated as being in trouble (Angerbjörn et al. 1995), and even the combined total populations for these border populations does not give grounds for optimism. The remnant populations in south Norway (Hardangervidda, Snøhetta) are clearly very isolated and are the most threatened with extinction (Strand et al. 1998c, Loison & Strand 1998, Loison et al. submitted). Combining the status data presented in **chapter 6** with that from Nordkalotten summarised by Frafjord & Rofstad (1998), it seems very likely that the Fennoscandian region contains no more than 200 adult individuals.

Although we have no statistical estimate of how complete our surveys really are, we believe that there are unlikely to be a large number of undocumented reproductions in each area, especially in southern Norway. Foot tourists, mountain wardens and hunters criss-cross the Norwegian mountains during all months of the year and are likely to notice a structure as obvious as a used arctic fox den, especially if pups are present. This is supported by the fact that although the total number of dens checked has increased in each year of the monitoring program, there has been no increase in the number of detected reproductions. This implies that the dens where reproduction occurs were known to our local contacts and have been included from the outset. In northern Norway (Troms and Finnmark) there is a greater possibility of unknown dens and unknown reproductions existing. However, even in this region reproduction only occurs in a fraction of the known dens, implying that the population is at a much lower level than in former times. It is difficult to design a survey system whereby a statistical measure of error could be determined. The very low density of arctic foxes means that any form of probabilistic survey will encounter very many zero values. In effect we are detecting presence/absence. However, the very large number of dens that are not in use is indisputable evidence that the populations are at very low levels compared to the early years of this century. Given these very low population estimates and the low genetic variation (Strand et al. 1998c) it would seem appropriate to change the status of arctic foxes on the Norwegian red list from Vulnerable to Endangered (Riden 1998).

8 Extinction in relation to area size

Population dynamics theory predicts that larger populations should have a lower risk of extinction than small populations (Loison & Strand 1998). In a territorial species which is confined to a relatively narrow habitat zone like arctic foxes (Angerbjörn et al. 1997, Landa et al. 1998a, Strand et al. 1998b) the population size should be proportional to the area of available habitat. Accordingly we tested the hypothesis that the probability of arctic foxes being extinct on a given mountain plateau was linked to the area of available habitat.

As arctic foxes only use a narrow range of altitudes (Landa et al. 1998a) we considered arctic fox habitat to cover an altitude range of 300m, centred on the regional mean altitude of occupied dens. Radio-telemetry data from Snøhetta indicates that this altitude range contained 75% of all telemetry locations. Four regions were used, Dividalen, Børgefjell, central mountains (Snøhetta, Trollheimen, Reinheimen, Forelhogna, Knutshø, Rondane, Sølenkletten) and the south-west (Hardangervidda, Nordfjella, Setersdal).

Within each mountain plateau we calculated the area of available habitat between the appropriate contour lines from 1:250 000 digital maps of Norway using ARC/INFO. We made no effort to compensate for the difference between map area, and true surface area on slopes. In addition for each plateau we calculated the area of alpine habitats from a digital national vegetation map. Most of the plateaux had natural borders, however in some cases we were forced to place somewhat subjective limits on plateaux, and in other cases we included outlying "islands" as part of the main plateau when they were only separated by very short distances, and shallow valleys.

The results (**table 3**) clearly show that arctic foxes have persisted in the largest mountain areas ($X^2 = 15.2$, df = 1, $p < 0.01$). Presumably the larger areas had larger populations to begin with, providing evidence for the hypothesis that larger populations have lower extinction risks than smaller ones. While this result is predicted from ecological theory, there have been very few demonstrations as clear as that presented here. Many studies have shown that small habitat patches (islands) contain fewer species than large patches (e.g. Brown 1971). The problem with these examples is that it is not possible to determine if a species absence is due to the fact that it became extinct, or that it never colonised in the first place. The arctic fox example presented here was aided by the fact that both historical records, and the former dens which are still visible, allow us to determine their former occupancy of mountain plateaux. Similar examples have been presented by Berger (1990) and Rodriguez & Delibes (in prep.), where larger populations of desert bighorn sheep (*Ovis canadensis*) and Iberian lynx (*Lynx pardinus*) persisted longer than smaller populations. This data provides direct support for the idea that a demographic process lies behind the non-recovery of arctic fox populations (Loison & Strand 1998, see next section).

Table 3 The range and map area of suitable arctic fox altitudes, and the total area of alpine vegetation, in 11 mountain plateaus. Documented arctic fox reproduction during the lst 10 years is indicated by a "1", no documented reproduction by a "0".

Plateau	**Suitable habitat**		**Area**		***Reproductio***
Area	**Min**	**Max**	**Arcitc Fox Habitat**	**Alpine vegetation**	
Sølenkletten	1100	1499	275	546	0
Børgefjell	800	1099	1660	1447	1
Dividalen	700	999	1626	3168	1
Forelhogna	1100	1499	193	1395	0
Hardangervidda	1200	1499	3526	11506	1
Knutshø	1100	1499	728	1332	0
Reinheimen	1100	1499	1551	3567	1
Rondane	1100	1499	1005	1609	1
Setersdal	1200	1499	552	4601	0
Snøhetta	1100	1399	1100	3386	1
Trollheimen	1100	1399	485	1502	0

9 Why have populations failed to recover ? Hypotheses

9.1 Original decline

The cause of the original decline of arctic foxes appears to have been over-harvest between the turn of the century and the mid 1920's (Hersteinsson et al. 1989). High fur prices and the state bounty must have motivated heavy trapping pressure into even the most remote mountain areas of Scandinavia. Such was the reduction in arctic fox density that many authors in the late 1920's and early 1930's questioned if arctic foxes had been hunted to extinction (Lönnberg 1927, Høst 1935). Unintentional mortality was also believed to be widespread following protection when arctic foxes fed on poisoned baits placed out for red foxes and wolverines (*Gulo gulo*) (Olstad 1945). In addition, a few individuals have been shot by mistake and killed by vehicles and trains over the years (Østbye et al. 1978, Østbye unpublished, Pedersen 1985).

The real conservation question is why arctic fox populations have not recovered from this over-harvest following 68 years of protection ? This is especially surprising when populations of larger carnivores have rapidly increased following protection during the last 10-20 years (Swenson et al. 1995, Landa et al. 1998b). A number of hypotheses have been raised over the years (Haglund & Nilsson 1977, Hersteinsson et al. 1989, Strand et al. 1998a). In our opinion none of these hypotheses alone can explain the non-recovery, although many of the factors may have negative effects on arctic fox populations. The following sections review the existing hypotheses and conclude with a new hypothesis which we believe explains the non-recovery and opens the way for a recovery program.

9.2 Lack of carcasses due to extermination of large predators

Large carnivores like wolf (*Canis lupus*), wolverine, bear and lynx (*Lynx lynx*) have not occurred in significant numbers in most alpine areas in southern and central Norway for at least 50-100 years following the introduction of state bounty payments in 1876. There has been a hypothesis in circulation that arctic foxes were dependent on scavenging from the remains of large ungulates killed by these large carnivores (Haglund & Nilsson 1977, Hersteinsson et al. 1989). This hypothesis appears to have developed from scattered observations of arctic foxes scavenging from large predator kills (e.g. polar bears, *Ursus maritimus*, on arctic sea ice). However, there are several lines of evidence against this; (1) There are no quantitative data to support the idea that carrion from large predator kills makes an important contribution to arctic fox diet (MacPherson 1969). (2) Arctic foxes are always found north of, or above, the treeline (Hersteinsson & Macdonald 1992, Landa et al. 1998a). In such habitats wolves occur at very low density (probably at the level of one pack per 500 -1000 km^2). Based on these densities it is unlikely that there would be a large amount of carrion left after the wolves had eaten a large ungulate kill, available within a given year within a given arctic fox territory. (3) In south Norway, wolves were hunted to very low levels *30-50 years before* the decline in arctic foxes (Elgmork 1996). (4) During the 1970's and early 1980's many of the wild reindeer herds in south Norway erupted to very high density. This led to very high rates of mortality among reindeer calves and yearlings through starvation (Skogland 1994). These carcasses would have been available to arctic foxes, but there was no increase in population density during this period. (5) Other scavengers like ravens (*Corvus corax*), golden eagles (*Aquila chrysaetos*) or crows (*Corvus corone*), are most likely to find carcasses first, and red foxes and wolverines are likely to be dominant at these kills anyway. There is also the risk that wolves would kill arctic foxes or take-over and enlarge their dens (Marquaad-Petersen 1994, 1998). (6) Lynx and wolverine recovery in northern Norway and Sweden during the last decade has led to increased predation on semi-domestic reindeer, but has not lead to any recovery of arctic foxes. (7) Arctic foxes are able to survive and reproduce in many environments that have always lacked large predators (Svalbard, Iceland, large areas of Greenland, islands off the coast of Alaska and Siberia).

9.3 Direct effects of climatic change

It has been claimed that there has been a slight warming of climate in Scandinavia during the last century, which might have reduced the area of alpine habitat and encouraged red fox expansion. (Hersteinsson & Macdonald 1992, Beniston et al. 1997). However, the data to support this is somewhat vague and contradictory due to the complications associated with interpretation of climatic and treeline date (Aas & Faarlund 1995, Oksanen et al. 1995, Hofgaard 1997). Although there is some evidence for an advance of the pine (*Pinus sylvestris*) limit in recent decades, there is also some evidence for a degree of cooling in some parts of Scandinavia during the last half of this century (Kullman 1993). It is clear that there have not been any dramatic changes in the treeline or in the productivity of the alpine environment during the last 70 years which are not within the level of variation observed during the last 9000 years (Moe & Odland 1992). It is therefore difficult to imagine that any recent climatic changes could have totally prevented arctic fox recovery, given their long term presence in Scandinavia (Frafjord & Hufthammer 1994) during periods which have shown many climatic shifts since the end of the Pleistocene. However, if present predictions of global climatic change are correct, then further warming of the climate could jeopardise the future of arctic foxes and the entire mountain ecosystem.

9.4 Interactions with red foxes

Arctic foxes and red foxes are very similar in behaviour and ecology (Hersteinsson & Macdonald 1982), although red fox life history is less adapted to the massive cyclic swings of the rodent populations (i.e. they have a smaller litter size), and their larger body size may make it difficult to satisfy their energy budgets in alpine habitats (Hersteinsson & Macdonald 1992). Red foxes have occupied many of the lower lying former arctic fox dens (Østbye et al. 1978, Strand et al. 1998a, Linnell et al. submitted). Because red foxes have occupied the most productive (low lying) areas of the arctic fox's former range they may have a disproportionate competitive effect. Although dens are important structures with a limited availability for foxes in alpine environments in general (Meia & Weber 1992) it is unlikely that arctic foxes compete with red foxes for dens, as most dens, and their surrounding territories, remain unoccupied and therefore resources are probably not limiting (**figure 2**). If there is competition for resources it is more likely to be between arctic foxes and small mustelids like weasel (*Mustela nivalis*) and stoat (*Mustela erminea*), than red fox. Densities of mustelids are likely to be higher, their numerical response to a lemming (*Lemmus lemmus*) peak will be faster, and they have an advantage in being able to hunt under the snow in winter (Henttonen et al. 1987, Korpimäki et al. 1991).

The other possibility is that red foxes are displacing or killing arctic foxes. Aggressive interactions and intra-guild predation between carnivores are common phenomena (Polis et al. 1989, Palomares in prep.). Swift fox (*Vulpes velox*), kit fox (*Vulpes macrotix*) and black-footed ferret (*Mustela nigripes*) recovery has been hampered by high rates of predation from coyotes (*Canis latrans*) and raptors in North America (Cypher & Scrivner 1992, Clark 1994, Eliason & Berry 1994, Ralls & White 1995). Arctic foxes are known to avoid encounters with red foxes, and in some cases pups are killed by them (Rudzinski et al. 1982, Schamel & Tracy 1986, Frafjord et al. 1989, Tannerfeldt 1997, Strand pers. obs.). However, it is unlikely that red fox density is sufficiently high to have a population wide effect across the entire alpine ecosystem. Also the red fox - arctic fox size difference is nowhere near as large as that between coyotes and small canids and mustelids mentioned above. The red fox population also only began increasing 20 years after protection of arctic foxes, and therefore cannot explain why the arctic fox population did not increase immediately after protection. Red foxes have been documented to breed in the vicinity of arctic foxes in many other study sites in Alaska and Canada without obvious effects. On the whole it is possible that red foxes play a role in limiting arctic fox distribution by displacing them from some low lying territories, but it is very unlikely that there are enough red foxes to have population wide effects. Predation by wolverines, rough-legged buzzards, and golden eagles on arctic foxes has also been observed (Garrott & Eberhardt 1982, Tannerfeldt 1997, Strand pers obs.) implying that intra-guild predation is a normal feature of arctic fox life, rather than being something new. In fact there are more observations of raptors killing and harassing arctic foxes than by red foxes (Frafjord 1991b, Menyushina 1994).

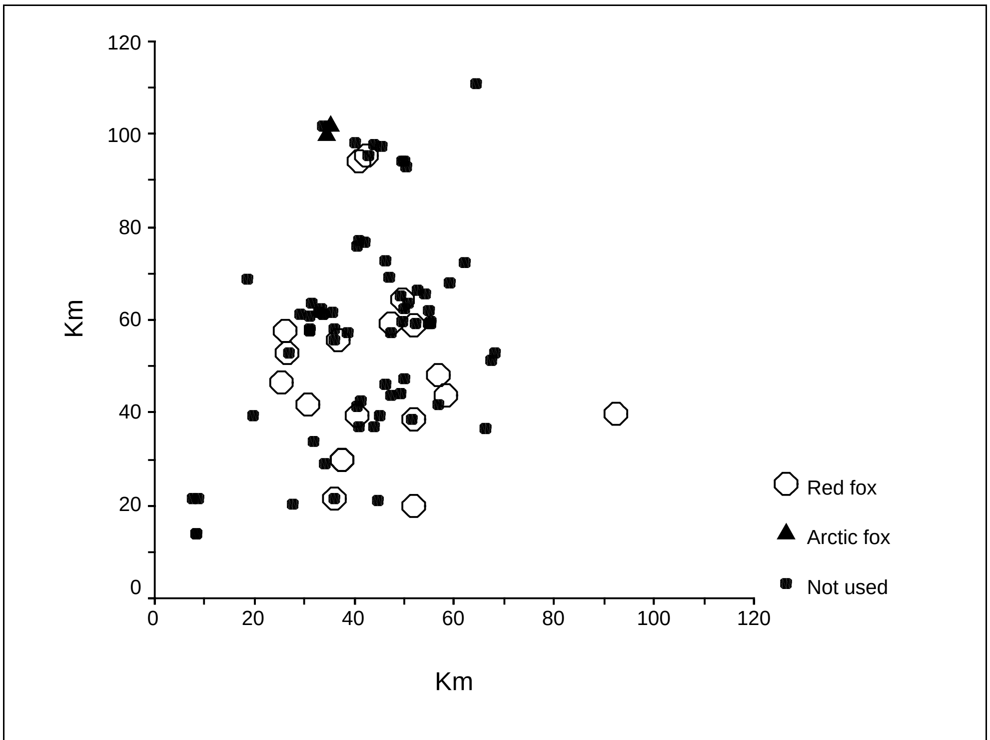


Figure 2 Map of all known former arctic dens which have been monitored within Hardangervidda. Symbols denote status as being presently used by red foxes, arctic foxes, or not in use. The many unused dens, and the large distances between used dens have lead us to reject competition with red foxes as being a serious limiting factor for arctic foxes.

9.5 Increased human disturbance

Arctic foxes are extremely tolerant of human disturbance and human structures (Eberhardt et al. 1982) and are unlikely to regard roads and other development as barriers to movement. Foods of human origin may provide an extra food source for arctic foxes, although they may also benefit red foxes. The Oslo-Bergen railway may have been a significant source of mortality to the relict population of arctic foxes at Finse in Hardangervidda, where on average a fox was killed every year or two (Østbye et al. 1978, Pedersen 1985) during the 1970's and 1980's. The present use of closed toilet systems should make the tracks less attractive as a foraging area. Although several arctic foxes were shot and trapped following protection (Østbye et al. 1978), it seems unlikely that illegal hunting is a serious issue today.

9.6 Negative impacts of escaped farm foxes

There are frequent reports of domestic arctic foxes escaping from farms (Frafjord 1985), however, there are very few cases of them breeding in the wild. Even if some did manage to breed there are so many empty territories that competition would be insignificant. There is therefore little reason to suspect their widespread involvement in population non-recovery. The greatest danger for the future is that diseases or parasites might be transferred to the wild populations. A second risk is the possibility of genetic introgression of domestic genes into the wild populations. Given the very low population levels of wild foxes, a single reproductive event involving a farmed fox could significantly change the genetic structure of the wild population. This issue clearly requires further work (see **chapter 11.6**).

9.7 Disease

It is possible that diseases of wild (e.g. scabies) or farm origin have influenced arctic fox populations. The available data on parasites and disease are very poor. There have been only a few documented cases of scabies in arctic foxes (Klaesson 1987, Mörner 1988), and no observed cases of the ear mite infection which has had extreme effects on some Siberian islands (Goltsman et al. 1996). Most importantly radio-collared and ear-tagged adult arctic foxes have shown relatively good survival rates (Tannerfeldt & Angerbjörn 1996, Strand et al. 1998b) which implies no disease process of significance. In addition, Norway and Sweden are rabies-free. There is however, an urgent need for more information about the health status of arctic fox populations.

9.8 Inbreeding depression

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). 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.

9.9 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, Strand et al. 1998d,e). Arctic foxes have very high litter sizes in these areas (Tannerfeldt & Angerbjörn in press). Models developed by Loison et al. (1998) have shown that this life history strategy of large litter size is an adaptation to the cyclic nature of resource availability. 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 & Strand 1998). 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 & Stenseth 1993, Pitelka & Batzli 1993, Stenseth & Ims 1993, Krebs et al. 1995, Potapov 1997, Strand et al. 1998e). As arctic foxes have been demonstrated to have a high dispersal capacity (Eberhardt & Hanson 1978, Garrott & Eberhardt 1987, Tannerfeldt & Angerbjörn 1996, Strand et al. 1998b, 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 (Strand et al. 1998e, Loison & Strand 1998). In effect arctic fox populations are dependent on a meta-population like structure where the sub-populations are units (territories, plateaux, mountain ranges) which 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 & Baker 1991, Hopper & 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 (Strand et al. 1998b).

In effect the turn of the century 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.

10 Can we secure a future for arctic foxes in Norway ?

Everything in the previous sections indicates that arctic foxes are in serious trouble in Norway. Both individually and as a whole the populations must be regarded as being highly endangered and under an imminent risk of extinction. The greatest mystery is how they have managed to survive as long as they have at such low levels. As there has been no recovery during 68 years of protection it is unlikely that they will recover without help. Therefore the question "can we secure a future for arctic foxes in Norway ?" needs to be asked.

The answer depends on three issues;

1) *Has the original cause of arctic fox population decline been identified, and corrected ?*
   Turn of the century over-harvest is generally accepted to have been the main cause of decline. Arctic foxes are now effectively protected.

2) *Has the cause of non-recovery been identified ?*
   The previous section describes a hypothesis (demographic trap hypothesis) that explains the cause of non-recovery based around the instability of the population when reduced below a critical level and fragmented to a degree that the stabilising influence of immigration is removed. Although not proven this is the first holistic hypothesis that has been advanced to explain arctic fox non-recovery. The actions advanced in **chapter 14** constitute an experimental test of this hypothesis.

3) *Is there still enough habitat for arctic foxes ?*
   Although there have been some changes in alpine areas during the last century we believe that there is still plenty of habitat suitable for arctic foxes. The fact that arctic foxes have been able to survive as long as they have implies that the habitat has not become totally unsuitable. Although there are some questions about the impact of heavy sheep grazing on vegetation and rodent dynamics (Seldal et al. 1994) there is no evidence for a serious breakdown in the ecosystem. Most of the changes are associated with human development of the alpine areas, especially road building and an increase in recreational activity. As arctic foxes have a relatively high tolerance of human activity these changes are unlikely to have been fatal for arctic fox populations (Eberhardt 1977, Eberhardt et al. 1982). Other lines of evidence include;

   - If red foxes are able to occupy at least some areas of the alpine ecosystem, that habitat should be able to support arctic foxes (see **chapter 9.4**).

- Radio-collared adult foxes in relict populations have shown a relatively good survival which does not support the idea that the habitat is of poor quality.
- Most rodent dependent raptors still exist in the alpine areas (Gjershaug et al. 1994). Although there appears to have a decline in numbers of snowy owls (*Nyctea scandiaca*) breeding in Norway during recent decades, there have been many documented reproductions during the period following the original arctic fox decline (Hagen 1952, 1960, Farner 1994, Gjershaug et al. 1994). In 1959, Hagen (1960) found 13 breeding pairs on Hardangervidda, but failed to observe any arctic foxes, despite the fact that many dens exist in the same area. This is strong evidence that even though the habitat was able to support lemming specialist predators, some other factor was hindering arctic fox recovery.
- Although quantitative estimates of prey availability do not exist, all the prey species that arctic fox require are still available.
- The absence of wolves is unlikely to be of critical importance, as they had been exterminated from most areas of south Norway in the decades before the great decline in arctic fox density.
- Pollution levels appear to be relatively low in Scandinavian arctic foxes (Strand et al. 1998f).
- It is conceivable that given the critically low densities of present arctic fox populations that even very low levels of interference/predation from red foxes are presently having a disproportionate effect, but this should not be important to a recovered population.

Everything points to the problem lying in arctic fox demography rather than the habitat. As 68 years of protection have not been sufficient to allow arctic fox recovery it seems obvious that some form of intervention is required to restore the arctic fox populations to their former range. In the following sections we present a 3 pronged action plan for arctic fox conservation and restoration. These centre around a continuation of the present monitoring and research programs, the need for a detailed management plan to protect the relict populations (in Børgefjell and Hardangervidda/Nordfjella) and a captive-breeding/release program to restore a properly functioning arctic fox meta-population to south Norway.

11 Further monitoring and research

The ideas presented in sections 9 and 10 are based on the best available knowledge of the status and ecology of Scandinavian arctic foxes. The level of knowledge has been dramatically improved by the research and monitoring conducted during the last 10 years in Norway and Sweden, although there are still many gaps in our understanding of arctic fox ecology which need to be filled. Research on other populations (Svalbard and Alaska) has also added to our understanding of arctic fox ecology in general. However, because the Scandinavian situation is special with respect to low population density, habitat structure (fragmented alpine habitats rather than tundra), and prey availability (cyclic rodents, no seabirds, few predators of reindeer apart from man), resources for research and monitoring need to be focused on Scandinavian populations.

11.1 Monitoring

Although the monitoring of arctic fox dens which has been undertaken in the TOV program (Terrestrial Monitoring Program, DN 1989, Kålås et al. 1994, Kålås et al. 1995, Strand et al. 1996, Strand 1997, 1998, Strand et al. 1998f, DN 1997) has not revealed effects of long distance pollution on foxes, the documentation of the critical status of arctic fox populations has probably been among the most noteworthy results of the program so far. It is important that the monitoring continue for at least three reasons; (1) Following the development of the population will increase our understanding of both the factors affecting Norwegian arctic foxes and extinction processes in general, (2) The results will serve as a control for any restoration work in other areas, and (3) The monitoring also follows the distribution and development of red fox populations in the alpine environment. This data is vital to further our understanding of the role of red foxes in arctic fox decline.

11.2 Research on Hardangervidda

The extra detailed monitoring and research of both arctic fox dens (over 100 dens) and of individual radio-collared arctic foxes that has begun in Hardangervidda should continue, with the expansion of the study area to include Nordfjella where there have been consistent reports of arctic foxes. The area is particularly important to study as (1) Hardangervidda is the largest alpine plateau in Norway and therefore should have originally contained the largest arctic fox population, and still might contain the second largest population outside Børgefjell, (2) Extensive background data exists on dens and den use spanning at lest 65 years (Høst 1935, Østbye et al. 1978, Pedersen 1985), (3) Because of the ecological studies based at the University of Oslo's research station at Finse, there is much background data on the functioning of the Hardangervidda ecosystem, (4) Hardangervidda is also one of the most likely candidates for restoration attempts. It is therefore important to document the baseline situation if the effects of restoration attempts are to be monitored. The survival of the radio-collared foxes will also assist in planning the restoration work. and (5) Having some radio-collared individuals will also assist in finding pups suitable for the captive-breeding program.

Finally the Hardangervidda monitoring/research project should include more detailed studies of red foxes. The role of red foxes in the alpine environment and in arctic fox non-recovery remains one of the biggest question facing our understanding of the decline of arctic foxes. The data that we need concerns the survival of red foxes in the alpine areas and the degree of dependence on immigration from lower lying forest habitats. Once field work has begun on one species it should not require much extra effort to include a second in the same environment.

11.3 Spatial aspects of prey dynamics

Data on the degree of spatial synchrony in small rodent population dynamics is central to both our understanding of arctic fox population dynamics and for planning arctic fox recovery. Although existing data points out that rodent cycles lack synchrony over large spatial scales (such as throughout Norway), data on a finer scale (for example within Hardangervidda) is lacking (Myrberget 1973). A simple system with a network of rodent trapping grids (total 10-20 sample fields) across Hardangervidda would complement ongoing work at Finse (University of Oslo) and DN's TOV monitoring program, and provide the necessary data (e.g. Steen et al. 1996).

11.4 Analysis of existing monitoring data

At present the ecological data from the Snøhetta and pollution studies is in the process of being printed in various Norwegian and international reports and journals. However, a good deal of valuable data exist in the results from the monitoring programs. Of special interest would be a den level, GIS based, analysis of the extinction and survival process. This would help us identify more precisely which habitats are important for arctic fox survival and to which landscape factors arctic fox survival is connected. Such work would be of vital help in planning recovery actions (see **chapter 14.4**).

11.5 Clarification of status in other mountain areas

Although extensive surveys and monitoring has been carried out in many of the mountain areas of Norway (**table 1**, Frafjord & Rofstad 1998), there are still some areas that have not been adequately surveyed (see **table 2**). As previously mentioned (section 11.2), Nordfjella should be included into the Hardangervidda project. Other priorities include Reinheimen, Jotunheimen, and the Norwegian mountains adjacent to the Swedish populations in NW Västerbotten and Norrbotten. Given the low levels of all the known populations, the discovery of an unknown remnant population would be significant. A combination of winter surveys for tracks and summer checking of dens should be sufficient to detect arctic fox presence.

11.6 Potential impact of farm escapes

The issue of genetic introgression of domestic genes into wild populations is currently very topical with respect to escapees from salmon farms entering rivers and either transferring disease or diluting genes of the local wild salmon. Although the issue of farmed arctic foxes escaping and coming into contact with wild foxes is directly analogous, very little attention has been directed towards it. Given the critical levels of wild populations, a full assessment of the potential impacts is required. Issues which need to be considered include;

(1) Location of active farms with respect to wild populations, and a review of security measures in regular use.
(2) Levels of disease among farmed populations.
(3) Methods to determine if a fox is of wild or domestic origin. This will require the evaluation of morphological and genetic markers, and a consideration of the potential need to ear-tag or micro-chip mark farmed foxes that occur close to wild populations.
(4) Research into the ability of farm escapes to survive and reproduce in the wild.

11.7 Effects of arctic foxes on biodiversity

Recent research has shown that carnivores can have ecosystem effects beyond the direct effects of their predation on prey populations. These include the effects of their digging and scent marking/defecation and the transfer of nutrients between different food chains (Ben-David et al. 1998a,b, Tardiff & Stanford 1998). The implication is that the loss of a carnivore species can have cascade effects through the ecosystem (Estes 1996). Potential effects of arctic fox extinction are most likely to be seen at the den sites. Digging, urination and defecation at dens is likely to change the micro-habitat through aeration of the soil and increased nutrient availability. Present data are insufficient to quantify potential effects of arctic fox extinction. However in areas like Børgefjell and Hardangervidda where a range of dens with different histories (currently in use, or known dates of last use) exist, it should be possible to collect data on the importance of arctic fox use of the site on plant and invertebrate diversity.

12 Management plans for the relict populations

If arctic foxes are to be conserved in Norway, care will be required to limit human activities and land use which could affect their survival. Accordingly, management authorities need to consider the requirements of arctic foxes within all of the identified relict populations (**table 3**). Because it appears that Børgefjell and Hardangervidda/Nordfjella (and possibly Snøhetta) are the last remaining arctic fox populations in Norway with any degree of viability they require special management. Accordingly, we recommend that arctic fox management plans should be drawn up for these areas. This should include the following aspects.

12.1 Continue monitoring

The monitoring of reproduction at dens that has been ongoing since the 1980's should be continued. Not only will this provide a vitally important time series for research purposes, but it will allow the detection of any declines and provide a control for the restoration work in south Norway. Emphasis should also be placed in searching for new dens within the area to ensure that our monitoring is as complete as possible. It is obviously important to co-ordinate this activity with Sweden as the mountain range spans the border. We have already established contact with Mats Ericson who is responsible for the monitoring of arctic foxes on the Swedish side.

12.2 Identify key habitats

By examining the reproduction records for the individual dens and by mapping the habitat availability around each den we should be able to identify which habitats explain variation in productivity. This will improve our understanding of the role of habitat in arctic fox ecology, and will determine which are the most important areas/habitats to protect. The habitat mapping will require either extra field work during the summers or the use of satellite imagery.

12.3 Identify possible threats

Through interviews with local managers, analysis of published data, and the habitat surveying field work, all possible factors that could potentially affect the arctic foxes need to be identified. Through the use of a basic GIS analysis it should be possible to overlay the "threats" with the "habitats" and "den locations" to identify areas in need of special protection. If enough data is available on other topics of conservation interest (such as breeding birds of prey) it should be possible to combine all layers into a detailed and spatially explicit management planning tool for the areas.

12.4 Contingency planning

If maintaining relict populations like Børgefjell or Hardangervidda/Nordfjella is a management goal there needs to be a set of management guidelines in place to handle any eventual threats to their survival. One possible scenario is the appearance of scabies in the arctic fox population. Scabies was documented in both red and arctic foxes frequenting a reindeer slaughteryard on the Swedish side of Børgefjell. In response, 21 arctic foxes were captured and treated for scabies (whether they had any signs of it or not) while being held captive. Subsequently all were released (Mörner 1988). In addition the slaughteryard was closed which reduced contact between red and arctic foxes. There was no sign of scabies among wild foxes captured during the following year, indicating that the intervention may have helped.

What happens if scabies (or some other canid disease like parvovirus or distemper) is documented among Norwegian arctic foxes ? Options vary from doing nothing through to vaccination and treatment of the entire population. Arctic foxes are relatively easy to detect and live trap which makes treatment of wild populations possible, and it is possible that some effective oral vaccines and/or treatments may exist. Another option is to begin to live capture a sample of foxes each year to allow blood samples to be taken to monitor the health of wild populations. Evaluation of these options requires consideration of logistic, veterinary and conservation issues.

A second issue concerns foxes which have escaped from farms. Given the low numbers of wild arctic foxes, the risks of disease transfer and/or genetic dilution need to be considered. Contingency plans for two scenarios need to be considered. The first is the occasional escape of a few individuals from farms. The second, and more important, scenario concerns a mass release from an entire farm. This could conceivably occur following a storm, or because of a deliberate release by animal rights activists (in the same manner as recent releases of farm mink in the United Kingdom). Rapid response should allow large numbers of escapees to be re-captured, shot or trapped. However, data on behaviour of escaped foxes would have greatly helped in planning such response operations.

For successful response to either the disease or farm escape scenarios it is vital that detailed management guidelines be evaluated and set in place *before* a situation arises.

13 Restoration of arctic foxes in south Norway: options

If our “demographic trap” hypothesis is correct, then the only way to reverse the decline is to return the population to a higher density, and to increase its continuos distribution and connectivity. This should increase the probability of the population surviving the critical years with low rodent availability that are the population bottlenecks in the cycle. However, there are three possible strategies to increase the population density which we review below.

13.1 Feeding

Attempts have been made in both Sweden and Finland to improve arctic fox reproduction and survival through the provisioning of supplementary food (Haglund & Nilsson 1977, Angerbjörn et al. 1991, Tannerfeldt et al. 1994, Kaikusalo & Angerbjörn 1995). Early attempts with the provisioning of whole ungulate carcasses during late winter in northern Sweden lead to the observation that red foxes, wolverines and ravens used the extra food more than arctic foxes, and that the arctic foxes did not use the extra food much when rodents were abundant (Haglund & Nilsson 1977). In northern Finland, extra food was provided at 6 dens in both winter and summer for 5 years. No increase in den occupancy or reproduction was observed for arctic foxes, however there was a resultant increase in red fox reproduction in the same area (Kaikusalo & Angerbjörn 1995).

The most intensive attempts at supplementary feeding have been undertaken in the Vindelfjällen nature reserve in northern Sweden. Experiments with the provisioning of both winter and summer food have been underway since 1985. Winter feeding was shown to increase both den occupancy and probability of pups being born, although there was no effect on the litter size of those that gave birth (Angerbjörn et al. 1991). Combined winter and summer feeding also increased the number of pups that survived until weaning, although there was no detectable effect on survival beyond the first summer (Angerbjörn et al. 1995, Tannerfeldt et al. 1994, Tannerfeldt 1997). The implications are that food availability was having an influence on reproduction and early survival, but that the amount of food provided did not allow the foxes to be independent of natural food sources. These experiments provide clarification of the process behind the dramatic population fluctuations that arctic foxes show with respect to lemming abundance (MacPherson 1969).

Despite the improved reproductive success of the fed foxes, there was no detectable long term effect on survival. This implies that for feeding to be used as a management tactic it must be provided year around so that survival is independent of natural food availability during the low years of the rodent cycle. Arctic fox recovery programs in Sweden are planning to put much emphasis on feeding as a means of increasing arctic fox density (Angerbjörn & Löftgren in prep.), however we do not believe that it is applicable in Norway for the following reasons;

(1) There is the danger of increasing red fox numbers. The main hypothesis for explaining arctic fox co-existence with red foxes is that arctic fox habitat contains so little food that red foxes cannot satisfy their energetic budgets.
(2) Artificial feeding sites will increase the probability of contact between arctic fox and other scavengers (e.g. golden eagles, red fox and wolverine). Apart from the possibility of intra-guild predation there is also the possibility of the transfer of scabies from red foxes to arctic foxes. Indeed anything that increases contacts between individuals either within or between the species is associated with an increased risk of disease and parasite transfer.
(3) The logistical problems of dispensing food over large areas of alpine habitat during large periods of the year.
(4) There is little ecological data to support the idea that food availability is particularly low in the alpine habitats of Norway. Many bird species which are also dependent on rodents, such as rough-legged buzzard (*Buteo lagopus*) and polar skua (*Stercorarius longicaudus*) are present and breeding in the mountains (Gjershaug et al.1994). As the Swedish study found no long term survival benefit following winter and summer feeding, it is clear that it will always be the level of natural prey in the mountains which ultimately limits survival.
(5) There are not enough foxes to feed. The Norwegian situation appears to be much worse than the Swedish situation. The relict populations in Norway are much smaller and more fragmented than those in Sweden. It would probably not be possible to find enough occupied dens to feed in Norway to have any rapid effects at the population level.

When the benefits of feeding are unclear, and the situation is as critical as it is in Norway, we cannot recommend entrusting the future of arctic foxes to a feeding program.

13.2 Translocation

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 along the Scandinavian peninsula is large enough to be able to act as a donor of adult foxes. Our 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. 1998c). In addition rabies is present in all these populations (Prestrud 1992, Prestrud et al. 1992) making them unsuitable for release in Norway which is a rabies free area. Preventing disease transfer is becoming an increasingly important issue in translocation projects (Griffith & Scott 1993).

13.3 Captive breeding

Although animals from captive-breeding are not the best option, they have been used successfully in many situations for many species (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). As the natural mortality of arctic fox pups is very high (Tannerfeldt & Angerbjörn 1996, Loison & Strand submitted), removing a small number (5-10) of pups from wherever reproduction occurs in south and central Norway should have a minimal effect on the donor population. These individuals could then be captive bred and the resultant offspring used to supplement a relict population in an attempt to restore that population. The following section contains a detailed proposal for such a captive-breeding and reintroduction program.

14 Restoration of arctic foxes in south Norway through population supplementation and reintroduction

14.1 Sources of animals for captive breeding

Although most of the relict populations of arctic foxes are at a very low density, there are usually at least a few documented reproductions each year at some dens within our monitoring program. We would propose to capture at least one female and one male pup from each reproductive den (up to a maximum of 10 females), irrespective of where it should be situated in Norway. The pups should be captured as close to the age of weaning as possible. This will make them easier to tame and thereby reduce the stress of entering a captive breeding program (Pedersen 1991), and will also enable the remaining pups to receive a greater share of parental investment which may increase their survival. As mortality will increase with age, taking pups early gives us the greatest access to the greatest number of pups. These pups should form the foundation of the captive breeding program. If not enough pups are captured during the first year, then more will be taken in subsequent years. Sperm could be obtained from wild males during the winter to increase the genetic base of the founders. Although the inter-breeding of animals from different parts of Norway will result in the loss of the area specific genetic patterns which our studies have shown to exist, it is not possible to capture enough pups from each area to breed an area specific lineage. In addition, there is probably a degree of inbreeding within each population (Strand et al. 1998c). The mixing of animals should help overcome any possible inbreeding depression. Although this plan of action may offend genetic purists, it is a pragmatic solution to a crisis situation (e.g. Herrero et al. 1986, Stanley Price 1989) and is the best practical solution.

14.2 Captive breeding

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 (Pedsersen 1991, Farstad 1993). The fur-farming industry has recently paid much attention to reproductive physiology (Farstad et al. 1992, Farstad 1993, Farstad et al. 1993, Valberg 1993) and stress reduction methods (Pedersen & Jeppesen 1990, Pedersen 1991, Moe 1996). This experience will be especially important when handling wild caught individuals which have not been subjected to the same domestication process as normal farmed foxes. Previous carnivore captive breeding programs have often had technical difficulties when pioneering methodology for a new species (Ginsberg 1994, Clark 1994). Based on the wealth of scientific and commercial experience with captive raising foxes the technical details of captive breeding should not be difficult to overcome. Hopefully between 5 and 10 breeding females could be used initially. This should allow the production of between 25 and 75 pups each year, most of which should be available for release. A releasable production of 20-50 pups each year would be sufficient, at least for the initial stages of the experiment.

14.3 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 early 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.

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 would 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 & 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.

14.4 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 continuos 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. The most likely candidate areas are within the Hardangervidda/Nordfjella ecosystem, with the Snøhetta, Knutshø, Rondane, Reinheimen complex as a reserve.

14.5 Release

Because of the problems of logistics in remote alpine areas we would initially plan a “hard release” (Carbyn et al. 1994) during August. This implies that small groups of pups would be released at a series of former arctic fox dens. Some food would be provided at each release site to help them survive the initial period, and to hopefully induce them to remain in the release area. Although hard releasing *may* result in wider post-release movements (Fritts 1992, Bangs & Fritts 1996, Linnell et al. 1997), and an initially higher mortality rate than “soft releasing”, the mortality rates should equalise after the first year (Carbyn et al. 1994). The release method would only be changed if the pups suffer extreme mortality rates in the immediate post-release stage, or display extreme post-release movements. Red foxes have often been proposed as a source of mortality for arctic foxes (Frafjord et al. 1989). At the age of release most pups should be large enough to escape from red foxes, and the pre-release conditioning should teach them to avoid interactions. As we wish to test the ability of released foxes to survive in the alpine ecosystem as it is today, control of red foxes will only be considered if after 1or 2 years release experience it can be documented that they are a major source of mortality for young pups in the immediate post-release period.

14.6 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. 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.

14.7 Education and information

At all stages of the project we will involve the media and use all opportunities to communicate both the direct objectives of the arctic fox restoration experiment and the problems facing the alpine environment in general. In effect we hope to use the photogenic arctic fox as a flagship species (Dietz et al. 1994). The assistance of foot tourists, hunters, fishermen and cabin owners will be requested in reporting all observations of foxes seen. The local mountain wardens (fjelloppsyn) will continue to be very closely connected to the project.

14.8 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 is very high during the first year of life, in cases it may reach 70-90% (Tannerfeldt & Angerbjörn 1996). Therefore we must expect the released captive bred pups to have similar, or even higher mortality 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.

These two criteria will be used to evaluate the success of the captive-breeding-release methods, rather than as acceptance of our critical-population-size hypothesis.

(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. This, together with the first two criteria, will allow us to accept the assumption that the alpine habitat is suitable for arctic foxes. After the first batch of wild reproductions we would not expect their to be many occupied dens that do not produce pups because of the absence of a mate (i.e. a reduction in allee effects). The observation of individuals immigrating into territories to maintain reproductive units after one of a resident pair has died will be one of the surest signs of our demographic trap hypothesis being correct. The number of occupied dens should also increase more in the experimental area than in any control area.
It needs to be emphasised that these are only preliminary criteria for short term success.

14.9 International co-operation

Arctic fox populations in Sweden and Finland are also at very low levels, indicating that arctic fox conservation is a Fennoscandian problem (Hersteinsson et al. 1989, Angerbjörn et al. 1995, Kaikusalo & Angerbjörn 1995). Sweden is currently preparing an action plan (Angerbjörn & Löfgren in prep.) for arctic fox conservation. Swedish researchers have invoked different explanations for arctic fox non-recovery including a lack of food, competition with red foxes and disease (Angerbjörn et al. 1991, Tannerfeldt et al. 1994, Angerbjörn & Löfgren in prep.), and their action plan concentrates on experiments designed to test these ideas. The differences between the Norwegian and Swedish action plans reflect the different status situations, geography and distributions of arctic foxes. Norwegian relict populations are much smaller, and fragmented to a greater degree, than the Swedish populations. The Swedish situation appears to be analogous to several Børgefjell sized populations. It is quite possible that different processes lie behind the non-recovery of populations in both countries.

We propose a high degree of co-operation and communication between Norway and Sweden, but that both countries should pursue their own action plans. This allows the greatest range of hypotheses concerning non-recovery to be tested. An annual meeting of both teams should be arranged to exchange ideas, report progress and discuss techniques. In addition, the possibility of joint publication of material should be considered where appropriate.

15 Implications for conservation in Norway

How can we justify such an expensive action plan for a species which is common on a global level (Ginsberg & Macdonald 1990) and when our proposed solution is only a test of a hypothesis ? The answer to this question needs to be considered on two levels - firstly on the level of the implications for Norway and secondly on the value of the scientific data gained (see next section). The rational of argument follows the seven points in favour of local level conservation proposed by Hunter & Hutchinson (1994) in an analysis on this issue.

15.1 Genetic diversity

The Scandinavian peninsula is the only place where arctic foxes survive on “islands” of alpine habitat surrounded by forest. In all other areas arctic foxes are found on arctic tundra, or arctic islands. Our genetic studies (Strand et al. in 1998c) have shown that Scandinavian arctic foxes represent a different genetic population compared to those from Siberia and Svalbard. The maintenance of genetic diversity at all levels (species, subspecies, region, population) is clearly an important objective of conservation. Therefore Scandinavian foxes represent a genetic resource that is desirable to preserve.

15.2 Ecological roles

Although there have been no documented ecosystem effects which can be directly attributed to arctic fox decline, the loss of a single predator in a species poor environment like that of the alpine plateaux of Norway could be expected to have disproportionate effects. With recent interest in the role of predators in the dynamics of cyclic prey populations (Steen et al. 1990, Korpimäki et al. 1991, Krebs et al. 1995, Reid et al. 1997) it could be speculated that arctic foxes may have a keystone role in the alpine system. The ability of arctic foxes to continue to eat lemmings even when they are in the low phase of the cycle implies that they may have an ability to deepen the trough of the cycle (Tannerfeldt 1997, Strand et al. in press).

15.3 Local values/Umbrella species

The alpine ecosystems of Norway figure strongly in local and national identity. The arctic fox is a very visible species, and its decline has received increasing public attention. Focus on its conservation should activate much local support and increase appreciation of the alpine ecosystem and the threats to its survival. Together with wild reindeer, the arctic fox is a perfect species to illustrate the importance of conserving large, unfragmented, habitats and preventing ecological problems rather than trying to fix them later. Norway is currently experiencing real conflicts with livestock in an attempt to protect populations of large carnivores (wolf, bear, lynx and wolverine, Aanes et al. 1996). Therefore it is important to have a conservation program aimed at a carnivore which is not surrounded by controversy and conflict. The important message from the arctic fox situation is that population recovery following over-harvest may not always be easy, or indeed possible, without expensive intervention.

15.4 Geographical limits of funding

The sources of funding that would be used here are exclusively national. Therefore the money is not being taken from sources from which international projects would also seek funding. Arctic foxes are probably the most threatened mammal species which is still reproducing in Norway today. Although bears and wolves exist at lower population levels, they are showing all signs of rapid recovery.

15.5 Think global, act local

Today, arctic foxes are not threatened at a global level (Ginsberg & Macdonald 1990) although some small island populations have declined (Goltsman et al. 1996, Fuglei et al. 1998). Prevention of global declines is also dependent on each country within a species range taking responsibility for its own wildlife populations. There is always the possibility that circumstances will change in other countries (canid populations are often subject to disease epidemics) so that the Scandinavian populations will increase in their relative importance.

16 Implications for the science of conservation biology

The results of this experiment will have a value that goes beyond national borders and the single species in question.

16.1 Arctic foxes as a surrogate species

The application of supplementation/reintroduction is a new science. Therefore any projects that are properly monitored add to the available pool of technical knowledge. The experience from such a project will quite possibly be very useful internationally for other projects on species with a greater global vulnerability, where making mistakes through inexperience would have much more severe consequences. Evaluating the success of pre-release training to reduce post-release mortality from starvation and predation is of especial importance.

16.2 Understanding the causes of population decline and non-recovery

The greatest value of the proposed supplementation/reintroduction project is to test our hypothesis about the link between species life-history and population vulnerability. Whether it succeeds in increasing arctic fox populations or not it will greatly increase our understanding of both what the problem is with arctic fox populations and of the causes of decline/non-recovery of carnivore populations in general. There are several other non-recoveries that need to be explained, for example European mink (Maran & Henttonen 1995). The results may shed light on the processes operating in such cases. The use of reintroduction projects as ecological experiments has been strongly advocated recently (Sarrazin & Barbault 1996) as an efficient way to simultaneously do conservation and learn about ecology. Following Sarrazin & Barbault (1996) the proposed restoration program would provide the following benefits for our understanding of ecology;

(1) It would test our understanding of ecological theory. By proposing the cause of decline as a hypothesis and the restoration program as an experimental test of this hypothesis, it allows a unique opportunity to test if our understanding of arctic fox demography is correct.
(2) Releasing large numbers of radio-collared individuals is the only way to obtain data on a large sample of arctic foxes. It would not be possible to justify such an extensive research program on arctic

foxes if it was not for the population crisis that they are undergoing.

(3) If the restoration project is a success it will provide a study area populated almost exclusively by individuals of known genetic relationship. This represents a unique opportunity for studying behavioural ecology.

(4) The process of colonisation is one of the least studied in ecology, because of the intrinsic problems of studying animals at very low density. The large numbers of “colonists” provided by a release program offers further unique opportunities to study the way they settle in the available habitat.

(5) Finally, if the release is a success and an arctic fox population is established, there will be the opportunity to compare the community ecology and prey dynamics in areas with and without arctic foxes. This will allow their possible role as a keystone species to be evaluated.

17 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.

Our explanation for arctic fox non-recovery is only a hypothesis. However, it is based on the sum total of our knowledge of arctic fox life history, population dynamics, and ecology. The principle aim of this restoration project is to test this hypothesis. If the results allow us to accept the hypothesis, then it should be possible to apply the release of captive-bred pups as a management method to restore populations over larger areas. If the results cause us to reject the hypothesis, then we must look elsewhere for an explanation for arctic fox non-recovery.

B. Sufficient habitat is protected and secure

Large areas of alpine habitat remain throughout Norway, 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. The only exception is the absence of the larger predators. The significance of their absence is hard to quantify, although it is very unlikely that wolf or lynx ever occurred at very high density in alpine areas. Wolverines are very ineffective predators of wild reindeer and are unlikely to be of significance as a provider of food. They are more likely to be a dominant competitor for carrion. Land use patterns in all alpine areas consist of sheep grazing, hunting for 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 most 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.

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 already begun to express an interest in the status of the arctic fox, so it should not be a problem to further encourage this coverage. Information leaflets can be distributed at strategic points in the study areas, informing about the project and requesting people to report any observations of foxes or active dens.

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

No captive population exists at present. However, given the experience available from the fox farming industry it should not be difficult to raise wild-caught pups in captivity and to use them as the founders of captive breeding lines.

H. Knowledge of the techniques of reintroduction exists

The primary author is a member of the IUCN reintroduction specialist group. This action plan will be reviewed by members of both the Reintroduction Specialist Group and the Canid Specialist Group. We shall work closely with veterinary 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. Negotiations are underway with the Norwegian Research Council, the Norwegian Institute for Nature Research, the environmental protection divisions of the various county management offices and the Directorate for Nature Management. Because of the publicity that this work should attract we hope to be able to attract substantial sponsorship from the commercial sector.

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. Our demographic trap hypothesis predicts that restoration of more continuos 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.

18 The consequences of doing nothing !

Arctic foxes have been protected for 68 years (1930-1998) in Norway, 70 years in Sweden (1928-1997) and for 58 years (1940-1997) 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 affects that could result in local extinction.

The implications are that the consequences of inaction are likely to be national (and probably regional) extinction. We can never be 100% sure that our understanding of the causes of non-recovery are correct and that our proposed restoration plan will work. The different proposed approaches to active conservation in Sweden and Norway can serve as two complementary experimental approaches to restoration. Hopefully for the sake of the arctic foxes, one of the approaches will be correct. However, whatever the outcome it will improve our understanding of the problems facing arctic foxes. Action is clearly better than sitting back and carefully documenting regional extinction.

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