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NINA Special Report 37

International conference on
ARCTIC FOX BIOLOGY

International conference on arctic fox biology

Vålådalen Mountain Station, Sweden
February 16-18th 2009

Program, abstract and lists of participants

Angerbjörn, Eide & Noren (red.)

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Welcome

In the 3rd International arctic fox conference, we present a scientific program with a broad scope ranging from genetics and general biology to community ecology and conservation issues. The topics covered are of high relevance for science, management authorities, rangers and public with special interest in conservation of the arctic fox.

The arctic fox is a flagship species for the arctic and alpine environment. Being at the top of the food chain, the arctic fox is a suitable indicator species giving notice and signals of ecosystem state and change. Displaying a broad spectrum of adaptations to the tundra ecosystem, the arctic fox is of significant interest regarding several behavioural and physiological aspects. The arctic fox show an astonishing variation in several life history characters, e.g. with a litter size from 1 – 18 cubs and a social organization from a breeding pair to complex social groups. Such contrasts are mostly not found within a single species and make the arctic fox especially suitable to test several life history theories. Further, the arctic fox is a species of conservation concern. Although found in numbers of several 100 000 throughout its whole circumpolar range in the northern hemisphere, local arctic fox populations at the edge of its former distribution are declining. In Fennoscandia, the arctic fox is critically endangered and threatened to go extinct. Despite soon 80 years of protection the population has rather continued to decline, the population has become fragmented and several small populations have recently gone extinct. Today, there are approximately 120 adult arctic foxes in Fennoscandia, of which approximately 50 are found in Sweden, 50 in Norway, and less than 10 in Finland. There are also populations on islands in the Bearing Strait that are threatened. In some cases foxes are severely invested by parasites and in others they are killed for different reasons. Environmental pollution is also a threat were the species is feeding on marine resources. In addition, the arctic fox is a species of economic value related to their valuable fur with hunting in Iceland, Russia, Canada and Alaska, although the hunting has decreased considerably in all areas. This conference will discuss all issues of arctic fox biology and hopefully all participants will get a deeper understanding of this fascinating carnivore.

Anders Angerbjörn, Nina E. Eide & Karin Norén

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Introduction

"Ecology of the Fennoscandian arctic fox – background and conservation perspectives"

Anders Angerbjörn, Stockholm University, Sweden

Session I – Community Ecology

Chair: Rolf Ims,

"The Arctic fox in the ecosystem: Knowns and unknowns"

Rolf Ims, University of Tromsø, Norway

This section centred in particular on two issues strongly affecting arctic fox population dynamics; namely the bottom-up effect of small rodent dynamics and the interspecific relation between the arctic fox and the red fox.

Two papers, from respectively east Greenland and Wrangel Island gave new examples, based on unpublished data, on the strong bottom-up effects of lemming fluctuations on population dynamics of the arctic foxes. The case from Wrangel Island is somewhat special in the sense that the intervals between lemming peaks (approximately 6 years) are longer and perhaps of lower amplitude than reported than for other locations in the arctic. In Greenland the cycles were more of the typical type with approximately 4 years between the peaks. These studies, originating from very different ecosystems support the notion that the signal of fluctuating lemming populations is translated into a clear response in the arctic fox population dynamics regardless of the periodicity of the cycle and different ecosystem context. The exceptionally comprehensive study at Bylot Island in the Canadian arctic, where many of the key interactions within the food web is quantified, was also review in this section of the conference. The Bylot Island study nicely illustrates how the arctic fox can transmit the "beat" of the lemming cycle to other components of the food web. The Bylot Island study also highlights the teleconnections between terrestrial arctic food web, the marine food web and southern ecosystem conveyed by seasonal movements to the sea ice of arctic foxes and south-north migration of geese.

The interspecific relation between the red fox and arctic fox were discussed in several presentations, in particular, with reference to the situation in Fennoscandia. Here like, in many other regions of the sub-arctic and the arctic, the red fox population has been increasing over the last century. Different hypotheses were presented to explain this increase including increased primary and secondary productivity due to changes in climate, anthropogenic land use (including infrastructure) and management regimes of ungulate populations and large carnivores. Recent analyses points to the combined action of different factors and that those different processes can be differentially important in different geographic regions. The relation between the red fox and the arctic fox may involve different mechanisms (exploitative and interference competition as well as predation). Although several instances of predation of red fox on arctic fox (juveniles and adult) have been proved, asymmetric competition is likely to be most important. The severity of the competition is, however, likely to be contingent on the ecosystem setting such as secondary productivity and its dynamics and the presence of other members of the predator guild. New field methods (remote cameras, satellite telemetry) and modelling is likely to shed new insight into the important interaction between arctic fox and the red fox in the future.

Arctic fox population dynamics on Wrangel Iseland during 28 years period

Nikita Ovsyanikov and Irina Menyushina
Wrangel Island State Nature Reserve, Russia

Arctic fox population dynamics on Wrangel Island is studied continuously since 1980. Research methodology combines stationary observations at 4 model areas (3 inland of the island, 1 on the coast) with route surveys over the island; breeding den mapping with consequent yearly monitoring of some dens; habitat and food resources evaluation. Direct behavioral observations have been carried out annually focusing on all types of arctic fox activities and interrelations with other species - snowy owls, prey species and larger predators. Particular attention was paid to arctic fox predation upon snow geese. Breeding fox den densities on the island varies between habitats of different quality from 0 to 3.75 dens per 10 km2. The most productive and stable fox breeding settlements are attributed to the best lemming habitats, with maximal fox breeding multy-year den number - 11 per 10 km2. Research period had covered 5 full lemming population cycles. Arctic fox population dynamics shows strict relation to lemming fluctuations. General trend over decades shows reduction of fox population productivity: average litter size at 1994 peak was 12.4 (n=8), at 2002 peak - 10.3 (n=9); length of fox population highs during the last decade was decreased. Diversity of fox breeding and foraging habitats within the island is important for maintaining the local fox population in long-term scale. Relative asynchrony of fox reproduction between different breeding settlements is thought to be important for recovery of the population after lemming depressions. Factors determining arctic fox population dynamics, productivity and survival are considered.

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Arctic foxes on Bylot Island, Nunavut, Canada

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We started in 2003 an intensive study of arctic foxes on Bylot Island (73°N, 80°W). This study builds on a less intensive monitoring program that was running since 1993. We now monitor about 100 dens distributed over a 600 km^2 area. The number of litters produced ranges from 5-20 and the number of adults and juveniles captured and tagged ranges from 15-25 and 25-50, respectively. During its first years, our study has concentrated on collecting traditional knowledge from Inuit Elders, describing selection of habitat for denning, and studying foraging and caching behaviour by foxes in a large snow goose colony. This was the "obvious way to start" given the characteristics of this population. We are now studying (stable isotopes) the role of the goose colony as a subsidy, the role of sea ice (Argos telemetry) as a platform for winter foraging, the role of lemmings (capture-recapture) as drivers of population dynamics, the role of distribution of food resources in the mating system (microsatellites), and the influence of red fox (arrived in the area in 1950) on arctic fox dynamics. This arctic fox population, which is not threatened, has thus access to lemmings, birds and seals, and faces recent competition from red fox. We hope that its detailed study can shed light on some of the community-level processes that drive arctic fox population dynamics.

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The Fennoscandian arctic fox – the victim of a top-down cascade or climate change?

Bodil Elmhagen, Steve Rushton, Gilbert Ludwig, Pekka Helle and Harto Lindén
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The Fennoscandian arctic fox population declined drastically in the early 20th century and has not recovered despite protection. Increased competition with the red fox is an important factor behind the non-recovery. It has been hypothesised that the red fox has increased due to mesopredator release, since top predators such as wolf and lynx were almost extirpated in the 19th century. In contrast however, community ecology theory predicts that the top-down impact of top predators depends on ecosystem productivity and is weak in unproductive tundra habitats. We use historic and recent data from Sweden and Finland to explore the relationship between red foxes and top predators in relation to bioclimatic productivity gradients. Statistical modelling of 19th century hunting bags indicate that declining top predator abundances triggered a mesopredator release of red foxes in productive southern Sweden, but not in northern counties with arctic foxes. Statistical modelling of winter track data from the Finnish Wildlife Triangle Scheme show that the re-establishment of lynx in the late 20th century has led to a gradual reversal of mesopredator release, where red fox abundances decline, but the impact of lynx depends on ecosystem productivity. Where lynx has regained functional significance, top-down control of red foxes increases with ecosystem productivity. Hence, our results do not support the hypothesis that the Fennoscandian arctic fox is a victim of mesopredator release following top predator extirpations. Instead, they may support a previously suggested alternative hypothesis: that the northern expansion of red fox populations is caused by climate change.

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Factors structuring the scavenger community on sub-arctic tundra

Siw Killengreen, Elise Strømseng, Nigel Yoccoz and Rolf A. Ims
University of Tromsø, Norway

The spatial and temporal distribution of carnivore species at high latitudes depends on the availability of winter food resources. In periods of scarcity of live prey, finding and exploiting carcasses is an advantage for those species that are able to efficiently locate and use such resources.

The aim of this study was to investigate the determinants of spatial-temporal variation in the structure of a scavenger community in sub-arctic tundra during winter. I focus on the distribution of species along a spatial resource gradient spanning from coast to inland tundra, and temporal variation in utilization of carcasses by scavengers, during changing light conditions. Data were obtained using cameras with time laps functions placed in front of reindeer carcasses. I used PCA and PCA with instrumental variables (PCAIV) to understand how environmental parameters influenced species distributions. We found a clear segregation between mammal and bird species mostly caused by light conditions. There was also segregation within the mammal group, with arctic fox avoiding competitors like red fox and eagles.

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Competition between arctic and red foxes - the importance of indirect and indirect interactions

Peter Hellström, Lars Liljemark, Anders Angerbjörn
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Interactions between predators are important structuring agents of both communities and food webs. Such intraguild interactions are often asymmetric, and range from indirect (exploitative) or direct (interference) competition to predation. Asymmetric competition can substantially decrease the probability of coexistence of species in carnivorous guilds, and it has been suggested that the ongoing expansion of the red fox into mountain tundra areas is a severe threat to long-term persistence of the arctic fox. However, the mechanism causing arctic fox populations to decline in the presence of red foxes is not fully understood. In this study, we investigated whether red foxes impact arctic foxes by means of pure exploitative interactions, or by a combination of exploitative and interference interactions.

The study was conducted between 2000 and 2007 in the Helags area (in the county of Jämtland, Sweden), where conservation efforts have been particularly intense. We did a large-scale experiment, where the two treatments were red fox removal and supplemental feeding in winter. Since primary prey, small rodents, is highly variable, we also had to account for phase dependent effects of the treatments. We studied the effect of these treatments on two response variables, number of breeding attempts and litter size.

We found that both treatments, supplemental feeding and red fox control, increased the probability of arctic fox reproduction at inhabited dens separately. Surprisingly, supplemental feeding was more important when lemming abundance was already high. However, red fox control together with supplemental feeding had a large effect also in the low phase of the rodent cycle. For litter size at weaning, foxes at supplementary fed produced about twice as many cubs when compared to control dens, but we saw no effect of red fox removal on litter size. The results strongly show that arctic foxes are food limited, and that red foxes affect arctic fox reproduction through exploitative competition rather than interference competition or through intraguild predation.

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The response of Arctic foxes to a fluctuating lemming population – Insights from a long term project in High arctic Greenland.

Johannes Lang, Benoît Sittler and Olivier Gilg
Institut für Tierökologie und Naturbildung, Germany

On a yearly basis for the past two decades (1988-2008), fluctuations of a lemming (*Dicrostonyx groenlandicus*) population have been closely monitored in the North East Greenland National Park, along with the responses of their predators. This simple vertebrate predator-prey community includes only four predators preying upon the lemming. The stoat (*Mustela erminea*) and the arctic fox (*Alopex lagopus*) are the sedentary predators sharing the community across the whole year while avian predators i.e. snowy owl (*Nyctea scandiaca*) and the long tailed skua (*Stercorarius longicaudus*) interfere only seasonally.

Lemming densities vary in a cyclic manner, with highest values in peak years not exceeding around 20 lemmings/ha while they may fall in depression phases to values below 0,1 lemming/ha. The arctic fox exhibits a type III functional response that starts to increase at much lower lemming densities than the responses of the avian predators, but it has only a weak numerical response. According to their specific responses, each predator plays a key role at some parts of the lemming cycle but only the stoat has the potential to drive the lemming cycle.

A comparison with the trapper data from the past century (1945 – 1959) for this region that exhibit cyclic patterns in the fur returns proves to be quite insightful and suggests that a cyclic pattern similar to those assessed in the present study was still prevailing.

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Beyond the red threat - what drives the red fox expansion

Nina E. Eide[1], Even Røhnebæk[1, 2], Børge S. Johnsen[1,3], Barbara Zimmermann[2], Kjetil Bevanger[1], Christian Nellemann[1], Vidar Selås[3]
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Human development alters habitats and landscapes, also in terms of resource availability for animals and plants. Resource availability is a strong limiting factor on species distribution and affects both inter- and intra-guild competition. Changes in species distribution and abundance may lead to species homogenization and local extinctions. We expect effects due to human development to be even stronger in marginal areas with limited over-all resource availability such as alpine ecosystems.

The red fox in alpine landscapes follows in the wake of human development, such as new cabin resorts, roads and power lines. The red fox tracks such areas for food resources. Human development in alpine landscapes alters alpine habitats from being characteristically instable, to become more stable and predictable both in terms of spatial and temporal availability of important food resources for red fox. Power tension lines cause higher mortality of birds, and hence increase prey availability at spatially predictable sites. Cabin resorts without garbage delivery scheme represent stable dumps of organic waste and important food resources to the red fox. During the last hundred years, Norwegian alpine landscapes have gone through massive changes caused by human development. Such changes open the otherwise unsuitable alpine habitats to the red fox, which might play an important role explaining the retreat of the arctic fox from the Fennoscandian mountains. Red fox has displaced the arctic fox and taken over important den sites in the low alpine tundra.

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Session II – Behaviour

Chair: Pàll Hersteinsson

"Behavioural ecology: an overview"

Pàll Hersteinsson
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The Arctic fox (*Vulpes lagopus*) is found in many different habitat types in its circumpolar distribution range. This is reflected in considerable variation in diet from one area to another as well as by season. Habitat types can, on the one hand, be divided into coastal and inland habitats, and on the other hand into areas inhabited by lemmings (*Lemmus* and *Dicrostonyx* spp.) and lemming-free areas. Coastal habitats generally have a higher and more varied prey availability than inland habitats while areas with lemmings have less predictable food abundance inter-annually than areas without lemmings.

Many aspects of the behavioural ecology of Arctic foxes are profoundly affected by patterns of food abundance in the habitat in question. However, activity patterns appear to be relatively invariable with season and area and are probably adapted to the optimisation of predation success. Caching of food during summer, for consumption as late as the following spring, is well established. Foxes may also switch habitats in some years and move or into the taiga or onto sea ice during winter. Marine food resources may be of importance during years of low lemming abundance for some populations.

Arctic foxes are generally socially monogamous although there are exceptions to this, with cases of both polygamy and polyandry, including litters with mixed paternity. Breeding pairs of foxes are generally fiercely territorial during summer and in some cases throughout the year, using scent, vocalisation and visual displays to signal territory occupancy. Both parents take active parts in rearing the cubs although the relative roles of the parents vary with the age of the pups. In some cases non-breeding foxes are present during the cub rearing period. The importance of these foxes ('helpers') to the reproductive success of the parents seems to be small but this may vary by habitat and has generally been poorly studied. Patterns of juvenile dispersal distances vary enormously between habitats. The proximal causes for the initiation of dispersal, exploratory movements and choice of area to settle and breed need further study.

Global warming is likely to affect Arctic foxes and evidence of this is already present. However, the effects will vary between habitats. Thus Arctic foxes are likely to suffer where they are in competition with red foxes (*Vulpes vulpes*) while elsewhere, such as in Iceland, Arctic foxes may benefit from increased primary and secondary productivity.

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Summer home ranges, prey and age of radio-tracked reproducing arcticfoxes *(Alopex lagopus)* on Traill Island North-East Greenland

Marek Zakrzewski
Forem International, Germany

Arcitc foxes *(Alopex lagopus)* were observed over from 1996 to 2004 on Traill Island in North-East Greenland. The summer home ranges of reproductive individuals were analysed by radio tracking and varied from 62 km² to 10 km². In years with only few lemmings *(Dicrostonyx groenlandicus)* the main prey were birds and in years with many lemmings those were the main prey as observed what the adults brought to the pups to the den. The minimum age of the foxes was determined by ear tacking. The longest observation period of one adult female fox were five conscutive years.

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Seasonal movements and sea-ice use patterns of arctic foxes on Bylot Island, Nunavut, Canada

Arnaud.Tarroux, Dominique Berteaux and Joël Bêty
University of Quebec at Rimouski and Centre d'Études Nordiques, Canada

Sea ice extent and duration are declining in the Canadian Arctic and the biological consequences of these declines are probably major. Information is needed on a large array of species to understand the consequences of declining sea ice on arctic ecosystems. Interestingly, declining sea ice not only affects marine ecosystems, but also terrestrial ecosystems because many terrestrial species use sea ice to travel between islands or to find food. The arctic fox (*Vulpes lagopus*) is well known to use the sea ice, and Inuit knowledge gathered in the Bylot Island area informed us on some of the patterns of sea ice use by the species in this region (C. Gagnon and D. Berteaux). Yet some critical aspects of the patterns of sea ice use by foxes are unavailable, especially at the individual level.

Here we present an ongoing study taking place on Bylot Island, Nunavut, where the arctic fox population is being monitored intensively since 2003. We show the results of more than one year of satellite tracking of arctic foxes. Between July 2007 and August 2008 we fitted 19 adults and 3 juveniles with Argos collars. These collars now allow us to track arctic foxes every day in summer and every second day in winter for one year. We show that if weaned juveniles seem to disperse rapidly from their natal area, adults tend to come back to their previous summer home range. Use of sea-ice in winter varies greatly from year to year, which could be explained by variations in available terrestrial resources.

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Winter movements of arctic foxes in northern Alaska measured by satellite telemetry

Nathan Pamperin, Erich Follmann and Brian T. Person
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We studied winter movements of 37 arctic foxes (*Alopex lagopus*) collared within a petroleum development area at Prudhoe Bay, Alaska (n = 20), and an undeveloped area in the National Petroleum Reserve-Alaska (NPR-A, n = 17) during the winters of 2004, 2005, and 2006 using satellite telemetry. Comparing Prudhoe Bay and NPR-A, differences in mean movement rates of juveniles was 23.9 ± 2.7 km per duty cycle and 10.6 ± 2.8 km per duty cycle for adults, and mean difference in maximum distance from capture site for juveniles was 265.2 ± 63.2 km and 205.5 ± 128.9 km for adults. Juveniles and adults collared in NPR-A were highly mobile and made long distance movements (up to 782 km) while foxes from Prudhoe Bay remained in or near the oil field throughout winter. Extensive use of sea-ice by three juvenile foxes from NPR-A was documented during the winter of 2005-2006. Three juvenile foxes traveled long distances (904, 1096, and 2757 km) during the winter and remained on the sea-ice for extended periods of time (76, 120, and 156 days). These findings verify the use of sea-ice by arctic foxes and raise concerns that the diminishing ice cover may negatively impact populations by limiting access to marine food sources. We conclude that the oilfields are having a strong effect on the winter movements of arctic fox and suggest differences in movements are likely attributable to the availability of anthropogenic foods at Prudhoe Bay.

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Maternal experience control the amplitude of intraguild predation on arctic fox offspring

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Interference competition between carnivores is an important factor limiting both distribution and abundance of the prey specie. The survival of the prey specie has been shown to be linked to individual experience with a lower survival for individuals that lack previous experience to a certain predator. Interference competition and killing between arctic (*Vulpes lagopus*) and red foxes (*V. vulpes*) are well described and is suggested to limit the southern distribution of arctic foxes and partly explain the non-recovery of the endangered arctic fox population at the Fennoscandian peninsula. However, few studies have investigated and quantified the effects of other predators in other as wolverines (*Gulo gulo*) and golden eagles (*Aquila chrysaetos*) dependent on individual experience of the prey. In this field study, we have investigated the juvenile survival of arctic fox cubs in relation to predators and experience of the mother by field observations and using remote cameras. The golden eagle was found to be the main predator exploiting the arctic fox cubs as a food resource, however, golden eagles were only observed on dens with mothers that were inexperienced first time breeders. Wolverine was visually observed once interacting with two adult arctic foxes, which managed to chase the wolverine away from the den. Red foxes were only captured by remote cameras once and did not affect the survival of the cubs at that particular den (all cubs survived the summer). The low number of red fox interactions is probably due to a high intensity of red fox culling in the area. For all litters (n = 12), the mean survival rate after weaning during the summer was 0.73 (CI 95% ± 0.16) (respondent to 30 days). For cubs with an inexperienced and experienced female, the survival rate was 0.42 (CI 95% ± 0.31) and 0.87 (CI 95% ±0.08), respectively.

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Interspecific killing of an arctic fox by a red fox was captured on video in the Prudhoe Bay oilfield, Alaska

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"Little is known about competitive interactions between red and arctic foxes in northern Alaska. Anecdotal information suggests that red foxes may be expanding their range into areas traditionally inhabited by arctic foxes and this may have negative consequences for arctic foxpopulations. In November of 2004, an instance of interspecific killing of an arctic fox by a red fox was captured on video in the Prudhoe Bay oilfield. We present this video and discuss the implications of increased competition between these two sympatric canids in northern Alaska."

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The battle of the mountains – Can the naivety of the arctic fox be its salvation?

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Variation in food availability and especially the recent decline in lemming population peaks hamper successful reproduction and survival in the remaining arctic fox populations. Furthermore, invasion of the slightly larger and superior red fox *Vulpes vulpes* into the arctic fox areas is believed to be a main threat for the successful conservation of the arctic fox. To day the arctic fox populations in Fennoscandia are too small to be viable and several conservation trials are carried out. These include supplemental feeding, red fox control and captive breeding. The captive breeding programme faces the challenge of re-introducing arctic foxes into areas that the meantime have been occupied by red fox. Theory suggests that introduction (in this case re-introduction) of a species to an area often fails when it already exist an allied species in the area, i.e. because the competition will be too intense. The arctic fox and the red fox can be characterised as close relatives, both being generalists and having overlapping diets. It is also shown that the red fox might dispel arctic fox from an area just by its presence. Historically, the two species showed little overlap and were they both existed, the arctic fox occupied the more marginal habitats (high alpine and high arctic tundra areas). In places without red fox, for example in Greenland, Iceland and Svalbard, the arctic fox is found in urbane areas, in inland and coastal areas as well as from the high arctic to the more temperate areas (i.e. Southern Greenland and Iceland). One of the challenges for arctic fox conservation is therefore to reduce the level of food competition with red fox. Could we utilize the naivety of arctic foxes according to humans and human artefacts compared to the suspiciousness of red foxes to the same factors? We constructed and tested a food dispenser exclusively made for the arctic fox. By this dispenser we were able to reduce the impact of intra guild-competition, and decrease the variation in food availability for the arctic fox. Trials carried out in connection with releases of captive breed arctic foxes are promising. Although food dispensers have been inspected from the outside by red fox, as well as other carnivores, only the naive arctic fox has so far been inside and utilised the food. By using this exclusive arctic fox food dispenser, we believe to be able to test the effects of food competition and/or food limitation on the arctic fox population growth following release-trials from the captive breeding programme of arctic fox in Norway.

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Caching of seasonally superabundant foods – to what extent do foxes use them?

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Food storage (termed food hoarding or food caching) is a common behaviour among birds and mammals. However, the extent to which animals use cached foods and how such use may change in response to abundance of alternative foods is unknown for most species. Arctic foxes cache thousands of eggs annually at large goose colonies and we estimated the contribution of cached eggs to spring and fall diets of arctic foxes by comparing stable isotope ratios (δ^{13}C and δ^{15}N) of fox tissues to those of their foods using a multi-source mixing model (Program IsoSource). Geese were not present in the study area in spring or fall so egg signatures in fox tissues therefore represented cached eggs. The contribution of cached eggs to arctic fox diets was inversely related to collared lemming abundance; the contribution of cached eggs to overall fox diets increased from <28% in years when collared lemmings were abundant to 30-74% in years when collared lemmings were scarce. Further, arctic foxes used cached eggs well into the following spring (almost 1 year after eggs were acquired) – a pattern which differs from that of carnivores generally storing foods for only a few days before consumption.

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The presentation was based on; Samelius G., Alisauskas R.T., Hobson K.A. and Larivière S. 2007. Prolonging the arctic pulse: long-term exploitation of cached eggs by arctic foxes when lemmings are scarce. Journal of Animal Ecology 76: 873-880

Session III – Physiology and Diseases

Chair: Eva Fuglei

Ecophysiology, parasites, diseases and environmental contaminants in the arctic fox: an introduction

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In order to better understand why wildlife populations inhabit a certain habitat, knowledge about how animals are adapted to the environment in which they live is of importance. High Arctic mammals, like the arctic fox, experience extreme contrasts in light and temperature in most of their distribution area. In winter the sun is below the horizon from late October to mid February, and there is 24 h darkness from November until the end of January (Polar night). In such areas, arctic foxes are exposed to temperature differences between the body core and the environment of as much as 100°C. When in addition, food is limited at least temporary, the challenge is to balance heat loss against the rate of metabolic heat production. The arctic fox is adapted to cold and low food supply through morphological (small rounded ears, short muzzle, thick fur, thick fat layer for insulation), physiological (fat deposition for energy reserve, counter current heat exchange in feet, lower critical temperature, metabolic depression) and behavioral (food caching, escape low temperatures seek shelter in snow lairs, curl up in a "ball") adaptations. Studies of Field metabolic rate in the arctic fox have not yet been carried out. Laboratory validation studies measuring energy consumption with double labelled water and indirect calometry simultaneously are needed to be able to conduct Field Metabolic Rate studies in free living animals. Large variations in reported Lower critical temperature among studies in the arctic fox imply that further studies needs to be conducted.

Other important factors affecting wildlife populations in different ways are parasites and diseases, as well as environmental contaminants. Parasites may, through their influence on individuals, play a significant role in their hosts' long-term population dynamics. Arctic foxes are hosts of many species of micro- and macroparasites. Some parasites have been shown to be an important mortality factor like rabies and toxoplasma, while other seems to play a minor role for the overall fitness of arctic foxes. Persistent organic pollutants (POPs) accumulate through the food chain, reaching highest concentrations in top predators like the arctic fox. POPs are lipophilic and arctic foxes are sensitive to contaminant exposure because they have seasonally high adipose levels. Lean arctic foxes have higher contaminant concentrations than fat

animals. Considering the high concentrations of POPs in arctic foxes of the coastal ecotype, in fact as high as reported for polar bears, their natural regular variation in body condition index (lean-fat cycles due to reproduction and starvation) on an annual basis makes these compounds bioavailable and to re-accumulate in vital tissue and organs resulting in possible toxic health effects.

Possible synergetic effects with contaminant and parasite burden, or global warming with increased competition and invasive species may increase arctic fox vulnerability to global change.

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Energy metabolism of growing blue foxes

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The blue fox (*Alopex lagopus*) is presently the most important species in fur farming in Finland. In recent years selective breeding has focused on producing heavy animals. At present blue foxes are fed ad libitum during the growing – furring period. The blue fox exhibits seasonal fluctuations in feed intake and accretion of body fat, feed intake and body fat retention being very high during autumn and early winter if fed unrestrictedly. The main objective of this project was to establish baseline data on the energy requirement of growing blue foxes.

Sixteen juvenile blue fox vixens were used and they were fed the same conventional diet. The animals were allocated to four different groups and given different energy supply in order to establish a population of animals with very different body condition. The experiment was performed in five 7d balance periods, starting when the animals were about 10 weeks old and ending when the animals were about 30 weeks old. Each period included a 22 hr respiration experiment by means of indirect calorimetry.

Mean live weights in groups were similar 4.81 -5.09 kg at the beginning of the trial. At the end of the trial the mean weights in the groups were from 9,23 kg to 12.83 kg. The feed consumption was different in the groups and the animals' live weight increased according to the energy supply. Animals were growing during the trial so the period had an effect on mean live weights in all groups. Further results on heat production, energy and protein metabolism will be presented at the congress.

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Autopsy findings in arctic foxes from Svalbard

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The arctic fox population on Svalbard hosts the zoonotic diseases rabies and Echinococcus multilocularus. As a disease surveillance, people on Svalbard are encouraged to deliver arctic foxes found dead to the Governor of Svalbard or the Norwegian polar institute. Foxes found dead during 1997-2008 were kept frozen and submittet for autopsy to the Veterinary Institute in Tromsø. The annual mortality of young foxes is believed to be high in the population on Svalbard and it has been estimated that only 26 % of the foxes survive their first year of living. Emaciation is likely and important cause of death in these young animals but the factors regulating the arctic fox numbers are not well understood. Emaciation was found as cause of death in 30% of totally 40 foxes. Rabies was diagnosed in two foxes from 1998 and 1999 but investigation of 621 trapped foxes from 1996-2004 shows that the prevalence on Svalbard is very low (unpublished date) and contributes little to fox mortality. Toxoplasmosis was diagnosed as cause of death in three foxes from 2000 and in two foxes from 2006. These were all young animals (4 months – 1 year) and the findings indicate that this infectious disease plays a role as a mortality factor. Traumatic cases such as bite wounds and traffic injuries were also found as cause of death.

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Toxoplasma gondii in arctic foxes on Svalbard

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The protozoan Toxoplasma gondii is widely found in most parts of the world. Virtually all warm-blooded animals may serve as intermediate hosts, whereas domestic and wild cats (Felidae) are the only definitive hosts known. Islands without the presence of cats have formerly been demonstrated to be free of T. gondii, or with only a very low frequency of the parasite. Three arctic foxes were found dead from disseminated toxoplasmosis in 2000. A following serosurvey showed a seroprevalence of 43% (n=594). A study of several mammal and bird species on Svalbard was initiated. No seropositive inidviduals were found among Svalbard reindeer (n=390) or sibling voles (n=361). In areas of the world where cats are present, the herbivores are commonly infected, probably through oocysts. The negative serological results in the Svalbard herbivores support the theory that there are no definitive hosts for T. gondii present in the terrestrial ecosystem. A seroprevalence of 7% was found anong barnacle geese (n=149). Geese are, together with other birds, a significant food source to the arctic fox on Svalbard during summer. The seroprevalence in barnacle geese indicates that geese may be a source of T. gondii to the fox population. Geese brooding on Svalbard winter in populated areas of Europe, and may play a key role as a migrating vector of T. gondii to the Svalbard archipelago.

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Endoparasites in two sympatric canids; Arctic and red foxes

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Parasites have been found to be an important component in populations and ecosystem dynamics. Factors like host social system, abundance and prey dynamics has been suggested to influence the density and distribution of parasites. Endoparasites have been identified to affect both fecundity and survival in several mammal species. In this study, we have compared the parasite diversity in arctic and red foxes, two sympatric living canids in the Fennoscandian peninsula. This was made to recognize if sympatric living arctic and red foxes should be considered as a single host population or if they are carriers of different parasitic fauna. Pathogenic endoparasites can be vulnerable to the small Fennoscandian arctic fox population, especially if the red fox, with a large population size, can function as a parasite reservoir. Faecal samples from 25 dens inhabited by arctic foxes and 40 culled red foxes were used for analysis of parasite occurrence. The results show that the two species share some endoparasites but differ in others. Though the two species inhabit the same geographical areas and prey upon the same species, the two species cannot be considered as a single host for all endoparasites species.

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Parasites in arctic foxes from Svalbard

Heikki Henttonen et al

Arctic Foxes on Shemya Island, Alaska: An Introduced Species with Unexpected Conservation Value

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Arctic foxes (*Alopex lagopus*) were introduced to Shemya Island, Alaska in the early 1900's. Subsequent programs to eradicate introduced foxes spared Shemya's foxes because they deter gulls and geese from roosting on the United States Air Force's runway. Recently, the deteriorating condition of the island's foxes prompted the Bird Air Strike Hazard program to conduct an assessment of the status and health of Shemya Island's fox population. Adult foxes and pups were live-trapped, sampled, and released. Moribund foxes were sacrificed, and necropsies including pathological and histological studies were performed. Island-wide surveys for adults and pups were conducted. Mouth ulcers were common among adult foxes and abnormal tooth wear was universal among foxes aged >1yr. Both conditions may be attributable to dietary deficiency and/or abrasive food items. Necropsies revealed benign and malignant tumors that may be linked to historic environmental contaminants. Shemya Island's population was estimated at 60-70 adult foxes. Although most foxes were thin and appeared to be in poor condition, reproduction was robust. Litters were observed each year (2006 & 2008), although percentage of pup mortality was unknown. Genetic diversity among Shemya Island foxes was low compared with Pribilof Island foxes (A.l. pribilofensis). DNA tests confirmed that Shemya Island foxes originated from Commander Island stock. Because one subspecies of Commander Island fox (A.l. semenovi) is critically endangered, Shemya Island foxes may represent an important genetic reservoir. Thus, a historically introduced species may provide contemporary benefits for conservation.

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Session IV– Population Genetics

Chair: Øystein Flagstad and Love Dalén,

Summary of the discussions

During the final discussion of the population genetics session, the recent proposed change in taxonomic name for the arctic, from *Alopex lagopus* to *Vulpes lagopus* fox was discussed. The reason for the proposed change is that leaving the arctic fox as *Alopex* would mean that the remaining species in the genus *Vulpes* would become paraphyletic (i.e. forming a taxonomic group that contained its most recent common ancestor, but not all descendants of that ancestor). The audience was divided among researchers wanting to continue the use of *Alopex* and those preferring the new genus name. It was generally agreed, however, that this question would be best settled in a different forum, for example the Canid Specialist Group of the IUCN.

The issue of inbreeding in the arctic fox was also briefly discussed, where the use of microsatellite markers have indicated an ongoing inbreeding problem in the Helags subpopulation in Scandinavia. Several researchers were of the opinion that this is an important issue that merits further studies in other geographic regions. The construction of a comprehensive pedigree for Scandinavia would be a valuable tool to investigate this issue.

Lessons from the past - climate change and range dynamics in the arctic fox

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Past changes in climate are believed to have resulted in large-scale changes in the distribution of, and divergence among, populations. However, the processes behind these changes are still relatively unknown. Genetic analyses on both modern samples and fossils have allowed us to track past population changes in the arctic fox over the last 100,000 years. The results indicate that the arctic fox's range has expanded during cold periods and been reduced during warmer climates, the latter being accompanied by local extinctions in the south rather than population contractions. In some regions, rising temperatures also seem to have caused a "sky island" effect, where habitat loss in lowlands may have led to increased population divergence.

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Applications of genetic analysis of museum specimens in conservation genetic studies: examples from the Scandinavian arctic fox

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In recent years, methods for extracting and analysing DNA from ancient tissues have been developed. Although, these methods still have some limitations due to the degradation of ancient DNA, they have provided an opportunity to directly study the effect of the historical processes that have created modern genetic patterns and variation in populations. In this presentation, I will provide examples of how museum specimens have been used in the study of the critically endangered Scandinavian arctic fox. In the examples, genetic data from museum specimens was compared to genetic data from the contemporary population, in order to (1) estimate the loss of genetic diversity in connection with a demographic bottleneck at the end of the 19th century, (2) examine the origin of the Scandinavian population, and (3) investigate the existence of farm foxes in one of the subpopulations. The results from all three studies demonstrate the advantage of using a temporal approach when addressing questions in conservation genetics.

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Arctic fox population structure: some patterns and processes on global and local scales

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Population structure reflects several aspects of both the organism and its environment. Movement is a major determinant of population structure, but the pattern of movement is influenced by several factors operating within and between populations. In small populations, genetic drift is another important process forming the genetic structure. The circumpolar Arctic fox (*Vulpes lagopus*) has high capacity for long-distance movement (>1000Km). Here, we present data from previous and ongoing studies to describe Arctic fox population structure patterns and processes on circumpolar and local scales. Microsatellite analyses imply genetic homogeneity and low impact of geographic distance between most Arctic fox populations worldwide, but have revealed Iceland and Fennoscandia as genetically differentiated populations. With focus on these two populations, we discuss the importance of different processes forming Arctic fox population structure within and between populations.

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(Appears only in printed version)

Hybridization and introgression of domestic genes in the Arctic fox: A threat to the persistence of free-ranging populations

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One threat to the persistence of the Scandinavian arctic fox is hybridization with escaped farm foxes. In this paper, we revisit the situation in the population on Hardangervidda in southern Norway. Previous analyses have shown that this population today is heavily influenced by foxes of domestic origin and that the original population of wild Arctic foxes went extinct. Using mitochondrial DNA and 10 microsatellite loci, we assess the history of the extinction event in more detail and track the source of the domestic gene pool. We demonstrate that a tourist hut, where breeding of farm foxes was started in the early 1990s, is the source of the domestic gene pool in the area. Our data further demonstrate that at least one hybridization event between a female of domestic origin and a male from the original wild population has occurred. Foxes of pure domestic origin in the area can all be traced back to the same origin, strongly suggesting that massive escape or more likely release of domestic foxes from the tourist hut has taken place over the last two decades. This heavy input of domestic foxes likely contributed to the extinction of the original wild population, from which the last known animal, a female, died in 2001.

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Session V - Management

Chair: Bodil Elmhagen

Threat or threatened? Arctic fox management in a circumpolar context

Bodil Elmhagen, Stockholm University

The arctic fox lives in remote tundra areas where the impact of man has been relatively weak. Over the last centuries however, the arctic fox has become the subject of three forms of management. It has been managed as a valuable species, as a pest species and as an endangered species. In the 19th century, an expanding fur industry replaced subsistence hunting. The arctic fox was generally resilient to high hunting pressure, but to increase the returns of valuable fur, it was introduced to several Arctic islands. This is one reason why it has become managed as a pest species. Introduced foxes caused havoc in island sea bird communities and changed the entire ecosystem. Other reasons why the arctic fox has been managed as a pest species are suggested damage to livestock and the fact that it is a major vector of rabies. The Fennoscandian arctic fox population stands out as one of the exceptions were hunting caused a dramatic decline in the early 20th century. The arctic fox was protected since it was a valuable resource at the time, but the population failed to recover. Today it is critically endangered and the subject of different conservation programmes. The non-recovery has been attributed to changes in the habitat which may result from climate change. Hence, there is a risk that the conservation problems of the Fennoscandian arctic fox population gradually will come to affect the status of the arctic fox in many parts of its circumpolar distribution area.

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Arctic fox in Finland

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Phase-dependent effect of conservation efforts in cyclically fluctuating populations of Arctic fox (*Vulpes lagopus*)

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Predator populations with demographic cycles driven by multi-annual cycles of their key prey resource can be expected to be "cyclic phase sensitive" to management actions. We explored this by means of modelling in the case of the highly endangered Fennoscandian arctic fox population which is driven by 4-year population cycles in small rodent prey. By using a model in which the management action improved arctic fox vital rate through increased resource availability, we show that arctic fox population growth was most improved when management action was applied in the increase and decrease phase of the cycle. Except in the low phase of the cycle, the growth rate was more affected when the management action worked through improved reproduction than improved survival. There was a synergistic effect to be gained by performing management action during multiple phases during a demographic cycle. Thus we recommend that arctic fox conservation programs ought to be continuous in time, but with the highest intensities of management action in the phases of the cycle in which the target population is most prone to respond.

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Monitoring arctic fox populations, what answers can it give?

Roy, Andersen, Nina E. Eide, Ivar Herfindal, Anders Angerbjörn, Heikki Henttonen, Matti Mela, Øystein Flagstad, Arild Landa and John Linnell

How to building a monitoring program on arctic foxes, protocols and data treatment. During the SEFALO+ period we have evolved a common protocol used for description and controls. Although different organization of the practical surveys in the different counties, Norway, Sweden and Finland, this allow all data to be pooled together to work at the level of natural populations rather than country boarders. Many of the arctic fox populations have a natural boarder stretching from west in Norway to east in Sweden/Finland. At today's population level, there are only a few mountain areas which could be considered subpopulations, with high chance of reproductions. The Fennoscandian arctic fox population has a typical metapopulation structure with long distance between subpopulations. Landscape analyses, considering both intrinsic demographic factors and extrinsic environmental factors can give insight to where the likelihood of survival is best, and where conservation measures should be completed.

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The Norwegian action plan for saving the critical endangered arctic fox

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In 2003 the Directorate for Nature Management (DN) presented an action plan for saving the arctic fox. This was the first official action plan on any endangered species in Norway. The plan contents a review of historic data on former arctic fox distribution also including hypotheses for the decline and non-recovery of arctic fox, and recommended actions to save the arctic fox from extinction in Norway. The Norwegian arctic fox is part of a common population shared by several countries (Sweden, Finland, and Russia), hence cross-border co-operation, especially with Sweden, was also emphasised in the plan. Based on recommendations in the action plan DN started four programmes, both to enhance the knowledge of the arctic fox and to increase the arctic fox population in Norway. In co-operating with research institutes and NGO's in Norway, DN started 1) a captive breeding and reintroduction programme, 2) a programme to evaluate the effect of red fox control as a conservation strategy for the arctic fox, 3) gathering regional monitoring initiatives to a national arctic fox monitoring programme with genetics as an important part, and 4) a information project. DN has also supported the Swedish-Finnish-Norwegian arctic fox programmes SEFALO and SEFALO+. Results from programmes based on the Norwegian action plan and results from SEFALO+ have been crucial for the revision of the Norwegian action plan to be accomplished in 2009.

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The Norwegian Arctic Fox captive breeding programme - history and status

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In Fennoscandia the Arctic fox *Alopex lagopus* is critically endangered due to environmental and demographic factors, e.g. competition and predation from red fox *Vulpes vulpes*. Low population densities gives low dispersal rates and restricts contact between mountain areas. A captive breeding programme based on wild born cubs was initiated in 2000. The initial fur farm design gave no reproductions and a breeding station in arctic fox habitat was established 2005. The station have eight 0.25 ha large enclosures with artificial dens and video-monitoring. The ultimate goal is to re-establish and strengthen small populations. One of 5 pairs bred in 2006, 4 of 6 pairs in 2007 and 6 of 8 pairs in 2008. Within the 11 litters produced so far, litter size varied from 2–11, averaging 5.8. Of a total of 64 cubs produced, 11 cubs died, 10 by infanticide and 1 by unknown causes. A total of 47 individuals have been used in release trials. Released animals are followed by telemetry, photo-boxes, transponders and genetics. Re-trapping confirm that the foxes are in good condition and no natural mortality has been recorded so far. Based on confirmed contact, survival first year is minimum 50%. I addition one pair in soft-release trial produced 5 cubs 2008. The methodology trials for release of captive born animals seems to be well functioning. Future releases will focus on few areas that have dens in high quality arctic fox habitat and connectivity of neighbouring populations and aims at testing survival rates in areas with and without red fox control. The captive breeding programme has potential to be a valuable measure to conserve the arctic fox in Fennoscandia.

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Do global environmental changes impact Arctic foxes of Wrangel Island?

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Long-term research on Arctic fox population ecology on Wrangel island (1980-to present) has provided essential data for detecting and monitoring species reaction to global environmental changes at local population level. As observed on Wrangel Island, factors related to environmental changes that negatively impact arctic fox population include the following. Arctic sea ice degradation cuts off alternative on-ice foraging opportunities for the foxes during seasons of lemming lows; prevents long-distance traveling of adults and off-the-island dispersal of young after breeding season; increases exposure of foxes scavenging on the ice to extreme situations; prevents return of mature foxes foraging on the ice to terrestrial ecosystems for breeding. Increased activity of wolves and wolverines causes: direct fox mortality from predation (wolverines) and killing-for-fun (wolves); shift of breeding arctic foxes from optimal dens to sub-optimal shelters in rocks at higher elevations; some changes in fox behavior. Repeated warming with icing during late autumn-winter seasons, with little snow accumulation during early winter, cuts off lemming winter breeding, causing prolongation of lemming depressions and reducing arctic fox food resources in tundra ecosystems. Sea bird colonies might become more essential alternative food resource for the arctic foxes under these conditions, but due to environmental changes their dynamics seems to be less stable. Alternative food resources for arctic foxes on the island are invertebrates and marine mammal carcasses cast to the beach by surf, and fish. Predation on snow geese decreased during last years due to decrease of arctic fox number. Perspectives for arctic fox survival are discussed.

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Poster session

The use of a seal rookery by Mednyi Arctic Fox (Alopex lagopus semenovi)

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Arctic fox of Mednyi Island (Commander Islands, North Pacific) utilizates nutrition source of the Southeastern Rookery, the breeding grounds of the Steller sea lion (*Eumetopias jubatus*) and the northern fur seal (*Callorhinus ursinus*). We studied the changes in the attachment of foxes to the rookery in the course of the pinniped breeding season (June-July), in 1998, 2004-2008. During all those years, the visitation of by arctic foxes of the rookery per day (the number of different animals recorded on the rookery in the course of the day, the total time spent by the animals on the rookery on a particular observation day) declined through the observation period. The decline of arctic fox interest in the rookery was particularly pronounced since late June. The decline is statistically significant in all the cases under consideration.

Whatever, the total abundance of the resource provided by the rookery in July (fur seals) is not smaller, and even considerable greater than in June (sea lions). That unexpected discrepancy between interest in the rookery and resource abundance can be accounted for the restructuring of the rookery during the last ten days of June when the harem sites of the fur seals are rapidly expanding. Probably, foxes are not well adapted to the difficult and aggressive environment of the rookery.

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Does increased family size lead to stronger protection of the den in Arctic fox on Mednyi Island (*Alopex lagopus semenovi*)?

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On Mednyi Island (the Commander Islands, the North Pacific) the arctic foxes form large families (up to 5-6 individuals). The aim of our research is to examine if the arctic fox cooperation gives the benefit with relation to protection of the litter. Of 1057 human passes of 101 breeding dens (data from 1994-2000, 2006, 2008), at least one adult resident was present at the den on 70,9% (749/1057) of passes. In complex groups with helpers and/or two lactating females there was one or more adults on 73,9% of cases (N=533) and in monogamous pairs on 67,7% (N=524). The rate of presence of at least one resident adult at the den for each family (considering only families that were observed not less then 5 times per season) was significantly lower in monogamous families than in complex families (Mann-Whitney U Test, U=399 ?<0,05, N1=37, N2=32). There was negative correlation between family size and rate of seeing the litter unattended (Spearman's rank correlation test: rs=-0.283, t(n-2)=-2.345, p<0.05, n=65) and positive correlation between family size and the number of adults guarding the litter at the same time (Spearman's rank correlation test: rs=0.398, t(n-2)=3.067, p<0.01, n=52).

The increasing of the litter guarding in complex families agree with the supposition that the necessity of the litter protection in conditions of the high population density could be one of the factors which determined the increasing of the family size in the insular population of arctic foxes.

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Ear mite and hair loss on the Mednyi Island: one or two diseases?

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The Medniy Arctic fox (Alopex lagopus semenovi) inhabits the Medniy Island of the Commander archipelago. The population maintained the stable high density for a long time in spite of the intensive hunting for pelts. In the middle 1970th a sharp decline in the population number occurred due to an increase in cub mortality (up to 90%). These mortalities were associated with extensive ear mange caused by the ear mite Otodectes cynotis. Normally the mites are limited to the auricle and don't cause severe disease or death. But in Medniy Arctic foxes mites spread over the entire body. Today, the population number is stable and but does not exceed 10-15 per cents of the pre-1975 level. While the cub mortality is descreased, each year almost all puppies on the island are infected with mites and more than 50 % of the pups show loss of hairs to different degrees.

In order to establish a possible reason for the observed skin disorder, we studied skin and hair samples from healthy individuals and ones with hair loss from the Mednyi Island. We found signs of unspecific epidermal cells necrosis, vacuolization in the epidermis and hair follicles, with oedema of the upper dermal layers, and the cuticle of numerous hairs was markedly corroded in all studied individuals from Mednyi independently of their condition and the mite infestation rate. Still unknown factors (probably specific environmental features, environmental pollution, immune or genetic disorder) affect the entire population causing an immune deficiency the hair loss.

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Geographical variability in size and shape skulls of the arctic fox *Alopex lagopus*, comparison with the red fox *Vulpes vulpes* variability

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Two subspecies of arctic fox *Alopex lagopus* on the Commander Islands have been isolated for an evolutionarily significant time in small territories. Comparative analysis of the biology of island and mainland populations of arctic fox has demonstrated a number of differences in characteristics of island populations, termed the «island syndrome» (Goltsman et al., 2005).

We have studied skull morphology differentiation of arctic fox form the Commander Islands and from the mainland territory of Russian North. Red fox *Vulpes vulpes* was used as an "outgroup" for comparison of magnitude of intra- and interspecific variation. A sample of 390 skulls of arctic fox from Mednyi Island, Bering Island and three locality from mainland and 382 skulls of red fox from five locality of Eurasia was examined. Variability of size and shape of skull and dentition was studied by means of standard and geometric morphometry.

Arctic foxes from Commander Islands are drastically different from mainland arctic foxes in size and shape of skull. The population from Mednyi Island is the most specific one as concerns both cranial and dental traits. Morphological differentiation between island and mainland arctic foxes is comparable to species differences between arctic foxes and red foxes. The correlation between size and shape changes is insignificant. The difference between island and mainland arctic foxes can not be explained by a shift along the age-related allometric vector, but is rather brought about by more complicated transformations of growth pattern.

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The predator guild structure in different tundra ecosystems in early spring

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Different predator communities were examined during spring in the tundra zone in a gradient from southern to middle and high Arctic. Four sites (two in Norway (Svalbard and Varanger) and two in Russia (Nenetsky and Yamal)) were equipped with 10 automatic cameras on reindeer carcasses. We analyzed the guild structure of scavengers and their spatial and temporal distribution.

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Captive breeding of the Arctic fox (*Alopex lagopus*): colour morphs, pair bonding and reproductive success

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The arctic fox captive breeding program is one of the measurements to save the critically endangered arctic fox population in Norway. The success of breeding in captivity depends on that we understand pair-bonding and behavioral traits of the foxes. Furthermore the program also allows us to study some fundamental traits that else is difficult to study in wild living animals. We tried to find out if the foxes were mating with the one we had decided, and how their reproductive success was related to different parameters. Social behavior, reproductive success and infanticide was recorded by vide monitoring and visual observation. The blue arctic fox is associated with coastal areas while the white arctic fox is associated with inland areas, due to their different camouflages (1). But despite of the blue foxes lack of camouflage against the snow in inland areas, there was no difference in the activity patterns, related to day and the year - between the two colour morphs. Amount of aggression and/or social behaviour seems not to say anything about their fitness (born and survived cubs). It was a positive correlation between number of born cubs and cub-survival, and a negative correlation between the birth year of males and the percent of survived cubs.

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Tourist effects on the behavior of denning arctic foxes in Iceland

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The arctic fox (*Vulpes lagopus*) is the only native terrestrial mammal in Iceland. In all regions they have been heavily hunted throughout the centuries. In the remote Hornstrandir Nature Reserve, arctic foxes have been protected since 1994. The area is a popular for hiking in the summer time but tourist season is mostly limited to July each year. To get to Hornstrandir, people come by boats since it is far north of the road systems. Most of the hiking trails pass the fox territories and some of them are very close to active fox dens.

The aim of this pilot-study was to measure tourist effects on the behavior and activity of denning arctic foxes in Hornvik, Hornstrandir, a pair of adult male and female.
We monitored the activity of the foxes at the den and the surrounding area. Special attention was made on adult fox responses to tourists passing by and their effect on duration and frequency of behavioral activities of the foxes, e.g. resting, barking, scent marking, leaving, arriving, bringing food etc. We did not register the pups behavior or interactions between pups and adults.

Observations were made in five day sessions in June (before tourist season) and July (high tourist season), monitoring were performed from 15:00 to 23:00 each of the five days. We also monitored tourist activity and fox response in August (low tourist season) but in another location of Hornstrandir, Adalvik. Adalvik is different from Hornvik since many landowners have summerhouses there and they tend to feed the foxes. These results were not used in statistical analysis.

In Hornvik, the female spent significantly more time at the den area than the male, both in June and July. A negative assosiation between tourists and males duration and the den in July, e.g. the male spent less time at the den area as the tourists stayed longer. We did not observe this assotioation at the female but she seemed to be more disturbed by the observation in June as she spent less time and visited the den fewer times as we came more often to the den in June. The male came more often with food to the den in June but in July, both parents brought food to the den and tourist traffic didn´t affect that behaviour. Male scent marking was significantly more frequent in July than in June but barking ceased considerably. It looked like the animals kept lower profile and more quiet territorial behaviour in the presence of humans.

These first results suggest some important torist effects on the behavior of denning arctic foxes but these were only the results of one pair. To improve the study, we would need more dens to compare, with and without tourist activity.

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Concluding remarks, sum up of questionnaire

Summing up on the knowledge and management of the arctic fox:
In the 80's we started to have some knowledge on the basic biology of the arctic fox, increasing through the 90's. In Scandinavia the arctic fox was still only protected and not managed actively. Under the 20's we gained increasing knowledge on the arctic fox in the community. The species became more actively managed in e.g. Scandinavia. Most decisions were however based on many assumptions explaining the lack of the arctic fox recovery. Community ecology got more and more attention, building the ground for knowledge based management. Ecosystem management should be the future managing the arctic foxes in Scandinavia. The global perspective is increasingly important as the human pressures are acting on the arctic fox throughout its distribution.

What more do we need to know?

Physiology
- Lower critical temperatures
- Field metabolic rate
- Environmental pollution (morphology/physiology)

Behaviour
- Winter behaviour, migration and social organization in relation to access and use of food resources
- Dispersal behaviour
- Helpers – win win or not?
- Paternity
- Blue/white ratio
- Differences male/female

Genetics
- Population structure – global
- Inbreeding and inbreeding avoidance
- Genetics and demography, morphology and diseases

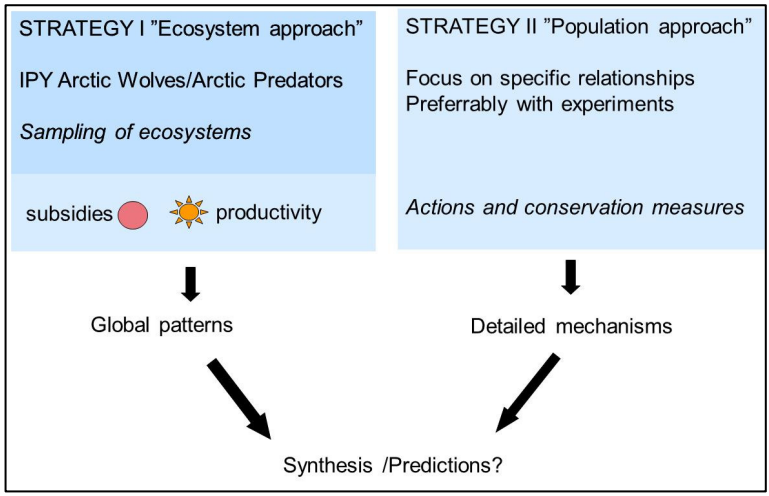
Demography
- Basic life history parameters (birth-death)
- Influence on resource availability (bottleneck)
- Lemming/rodents – signal mechanisms
- Plasticity and fixed traits (cost/inland morphs)
- Metapopulation dynamic and implications on. dispersal (natural/feed)
- Competition with other species (predation/fear/avoidance)

Effects of stressors

- Diseases & parasites
- Pollution (coastal foxes vulnerable)
- Climate change (less snow, warmer, no red foxes)

Community – interactions

- Lack of rodent peaks – global challenge
- Lemming/rodent – arctic fox - climate
- Arctic fox – red fox interactions (threshold balance)
- Wolverine – arctic fox – reindeer (benefits or not)
- Large carnivores – mesopredator release
- Interaguild relationships
- Effects of different subsidies
- Effect of diseases
- Climate driven changes (productivity, lemming cyclisity)
- Other human driven pressures (subsidies)



Management

- Are we using relevant conservation measures?
- We need good methods to measure success of measures!
- We need to optimize conservation efforts, e.g. according to lemming phase
- Is there a critical population size for survival?
- Need to move towards knowledge based management
- Can we really make good predictions??
- The case of the arctic fox is relevant to management of other Canids facing the "same situation". The red fox challenge several ecosystems.

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Important information sites for arctic fox at the web

Ongoing research on arctic fox and project web sites, up date from participants. To be filled out during the conference.

Norway
Arctic fox in Finnmark, northern Norway;
Arctic fox projects in NINA;
Management of arctic fox;
Public information site; www.fjellrev.no
IPY arctic predators
Arctic fox in the arctic

Sweden
Stockholm University, SEFALO+

Finland

Iceland

Greenland
Zackenberg

Russia

Canada
IPY arctic wolves

USA

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