5th International Conference in

ARCTIC FOX BIOLOGY

2017 | Rimouski | CANADA

Program book

12-15 October 2017
Université du Québec à Rimouski

We greatly thank the following for their support

Chaire de recherche du Canada en biodiversité nordique	*Organization of the Conference*
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Program, abstracts and list of participants
5th International Conference in Arctic Fox Biology
Université du Québec à Rimouski
Québec, Canada, 12-15 October 2017

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Université du Québec à Rimouski
Rimouski, Québec, Canada

Contents

Welcome Word

We are pleased to welcome you in Rimouski, Canada, for the 5th International Conference in Arctic Fox Biology, taking place from October 12th-15th, 2017 on the campus of the Université du Québec à Rimouski.

Why a conference about the arctic fox? This species is a central piece of the food web of most arctic ecosystems. It can be found in the tundra, on the sea ice, on top of mountains, on some of the most remote arctic islands, and even at the North Pole. As such, the arctic fox has long attracted the attention of scientists interested in northern ecology, in extreme physiological adaptations, or more recently in the effects of climate change on ecosystems. The arctic fox lives in all countries with territory in the Arctic: Canada, Denmark (including Greenland), Finland, Iceland, Norway, Russia, Sweden and the United States. It is a symbol of the Arctic Council, a high-level intergovernmental forum, and appears prominently on its logo.

The International Conference in Arctic Fox Biology takes place every fourth year and is the most important forum for researchers, conservation managers, policy makers, tour operators, students and any other people interested in this unique species and its northern habitats. Held for the first time in North America, this edition has as central theme: *Fostering International Collaborations*.

Building on productive discussions during the last Arctic fox conference, held in the Westfjords of Iceland in 2013, the conference starts with a one-day technical workshop. We will continue with two full days of oral presentations and posters, which will all address arctic fox research, conservation and management.

Saturday night will be a special night as the *Vulpes lagopus* banquet will be held in downtown Rimouski. The conference will end by a post-conference tour in Parc national du Bic on Sunday. This post-conference tour will be a great opportunity to socialize and will celebrate the vibrant fall colors of the Bas-Saint-Laurent region, as well as the harbour seal, Parc national du Bic's animal emblem.

We hope that you will enjoy your stay and your participation in the conference!

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Dominique Berteaux and Sandra Lai,
on behalf of the Organizing Committee

Map

Université du Québec à Rimouski (UQAR)
300 Allée des Ursulines, Rimouski, QC, G5L 3A1
1 418-723-1986

Hôtel Le Navigateur
130 Avenue Belzile, Rimouski, QC, G5L 3E4
1 418-724-6944

Les Complices
108 Rue Saint Germain E, Rimouski, QC, G5L 1A6
1 418-722-0505

Central Café
31 Rue de l'Évêché O, Rimouski, QC, G5L 4H4
1 418-722-4011

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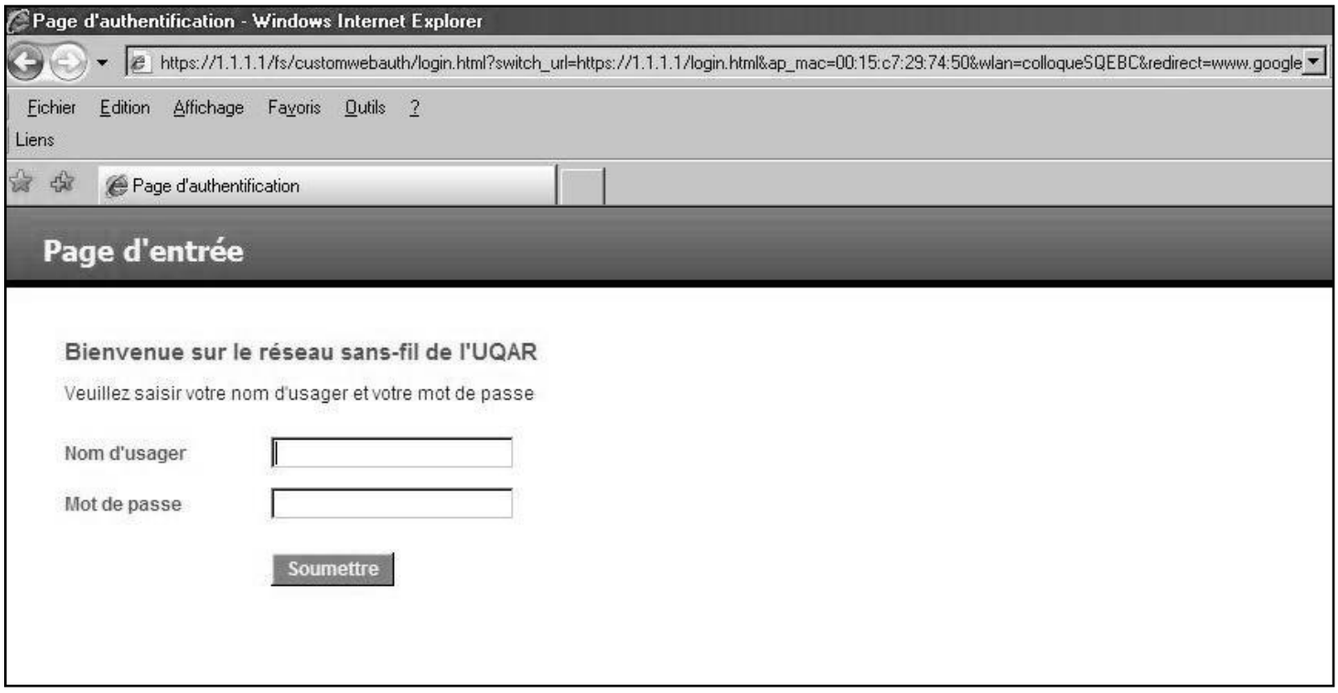
Network name: **UQAR-invite-Rimouski**

After detecting the signal, open your internet browser.

You will get the following authentication page:

Nom d’usager (username): **usager**
Mot de passe (password): **animal109**



Program

Thursday 12 October

07:30-09:00 **Registration**
09:00-10:30 Workshop
10:30-11:30 **Break**
11:30-13:00 Workshop
13:00-14:00 **Lunch**
14:00-15:30 Workshop
15:30-16:00 **Break**
16:00-17:00 Workshop
17:00-18:30 **Registration and icebreaker**
19:00-22:00 **Dinner (pay-your-own) at Central Café**

Friday 13 October

07:30-09:00 **Registration (poster set-up)**
09:00-09:30 **Welcome word**
09:30-10:30 **Session I - Fennoscandian Arctic and Russia** (Session Chair: Sandra Lai)

- 9:30-9:45 *On the edge: The Arctic fox in the Fennoscandian Arctic*
  Rolf Ims and Dorothee Ehrich
- 9:45-9:57 *Vole abundance and reindeer carcasses determine breeding activity of arctic foxes in low arctic Yamal, Russia*
  Dorothee Ehrich *et al.*
- 9:57-10:09 *Arctic foxes dominate the predator guild in low arctic Yamal, Russia*
  Aleksandr Sokolov *et al.*
- 10:09-10:21 *What resources subsidize arctic fox breeding in Sabetta, high arctic Yamal (Russia)?*
  Natalia Sokolova *et al.*
- 10:21-10:30 Period of questions for Yamal

10:30-11:30 **Break (poster set-up)**
11:30-12:00 **Summary of yesterday's workshop**
12:00-13:00 **Session II - North America** (Session Chair: Rolf Ims)

- 12:00-12:15 *Top-down regulation of lemmings by Arctic foxes and other predators: observations and experiments on Bylot Island*
  Dominique Fauteux *et al.*
- 12:15-12:30 *Are demographic parameters of adult Arctic foxes resource-dependent?*
  Clément Chevallier *et al.*
- 12:30-12:45 *Fine-scale genetic structure of the arctic fox population of Bylot Island (Nunavut, Canada)*
  Sandra Lai *et al.*
- 12:45-13:00 *Are arctic fox reproductive dens vulnerable to climate change in the Canadian High Arctic?*
  Florence Lapierre Poulin *et al.*

13:00-14:00 **Lunch (posters)**
14:00-15:30 **Session III - North America** (Session Chair: Natalia Sokolova)

- 14:00-14:15 *Satellite tracking of Arctic foxes on the Canadian Arctic sea ice*
  Dominique Berteaux
- 14:15-14:30 *Arctic foxes facilitate trophic and non-trophic interactions at the edge of the Arctic*
  Jim Roth
- 14:30-14:45 *Arctic fox rabies in a warming Canadian Arctic, 1953-2014: from surveillance to ecological mechanisms*
  Audrey Simon *et al.*

14:45-15:00 *Modeling rabies transmission in the arctic fox: toward a comprehensive picture of risk exposure for dogs and people in the Canadian Arctic*
Patrick Leighton *et al.*

15:00-15:15 *Transmission dynamics of Toxoplasma gondii in Arctic foxes (Vulpes lagopus): A long term mark recapture serological study*
Émilie Bouchard *et al.*

15:15-15:30 *Population status of the endemic Pribilof Fox Alopex lagopus pribilofensis: Continued decline amidst escalating threats is cause for concern*
Paula White

15:30-16:00 **Break (posters)**

16:00-17:00 **Session IV - Svalbard and Greenland** (Session Chair: Ester Rut Unnsteinsdóttir)

16:00-16:15 *Impact of harvesting on demographic and genetic structure of the Svalbard arctic fox population*
Eva Fuglei *et al.*

16:15-16:30 *An integrated approach for modeling environmental effects on population dynamics of the Arctic Fox in Svalbard*
Chloé Nater *et al.*

16:30-16:45 *The responses of arctic foxes to lemming cycles in North East Greenland as assessed through a 30-year long term monitoring*
Benoît Sittler *et al.*

16:45-17:00 *Space use of Arctic fox in Greenland*
Olivier Gilg *et al.*

17:00-17:05 **In memoriam Páll Hersteinsson**

17:05-17:30 **1-minute presentation of all posters**

17:30-19:00 **Poster session and icebreaker**

19:00-22:00 **Buffet dinner at UQAR**

Saturday 14 October

08:30-10:00 **Session V – Scandinavia** (Session Chair: Jim Roth)

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Jan Paul Bolstad

08:45-09:00 *Status and conservation goals for the critically endangered Arctic fox in Scandinavia. When is the mission completed?*
Nina Eide *et al.*

09:00-09:15 *Genetic consequences of conservation management: the case of the arctic fox (Vulpes lagopus) in Scandinavia*
Elisa Keeling Hemphill *et al.*

09:15-09:30 *The Swedish arctic fox – a model system for the extinction vortex?*
Karin Norén

09:30-09:45 *Genetic rescue in an inbred arctic fox population*
Malin Hasselgren *et al.*

09:45-10:00 *Demographic and genetic rescue in an arctic fox (Vulpes lagopus) subpopulation*
Johan Wallén

10:00-11:00 **Break (posters)**

11:00-12:30 **Session VI – Scandinavia** (Session Chair: Benoît Sittler)

11:00-11:15 *Conservation biology of the arctic fox – effects of sarcoptic mange*
Anders Angerbjörn *et al.*

11:15-11:30 *Seasonal camouflage and climate change – Phenological mismatch in the Arctic fox?*
Dick Moberg *et al.*

11:30-11:45 *Litter sizes and territory quality – Is there a landscape effect on reproductive investment in lemming foxes?*
Rasmus Erlandsson *et al.*

11:45-12:00 *Parent personality influences juvenile behaviour and mortality in Swedish arctic foxes*
Seoyun Choi *et al.*

12:00-12:15 *Mutual relationships between tourism and arctic fox conservation*
Malin Larm *et al.*

12:15-12:30 *Bringing the field to your phone*
Sandra Jönssen

12:30-13:30 **Lunch (posters)**

13:30-15:00 **Session VII - Scandinavia, Iceland and the rest of the world** (Chair: Paula White)

13:30-13:45 *Individual use of feeding stations - Who's eating all the food?*
Kristine Ulvund *et al.*

13:45-14:00 *Survival of captive-bred and released versus wild-born Arctic foxes in Norway*
Arild Landa *et al.*

14:00-14:15 *Is there hope for the arctic fox in Finland?*
Heikki Henttonen *et al.*

14:15-14:30 *Home ranges and territoriality of island arctic foxes under abundant food conditions*
Anton Pletenev *et al.*

14:30-14:45 *Does it pay off to breed young? Demographic response to heavy hunting pressure during the breeding season*
Ester Rut Unnsteinsdóttir

14:45-15:00 *Exploring different methods of visual storytelling to help communicate Arctic fox (Vulpes lagopus) research*
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15:00-15:30 **Break (posters)**

15:30-16:45 **Session VIII - Methods and other species** (Session Chair: Anders Angerbjörn)

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Eric Devost *et al.*

15:45-16:00 *Genomics in arctic fox conservation and ecology: development and utility of the custom fox Affymetrix 702k array*
Ingerid Julie Hagen Arnesen *et al.*

16:00-16:15 *Diversity of the Major Histocompatibility Complex gene, DRB1, in Arctic Fox (Vulpes lagopus)*
Stephen Harrison *et al.*

16:15-16:30 *Impact of personality: relevance of findings from swift, San Joaquin and island fox conservation to arctic fox*
Samantha Bremmer-Harrison

16:30-16:45 *Evaluation of invasive and non-invasive methods to monitor lemming abundance in the Canadian Arctic*
Gilles Gauthier *et al.*

16:45-17:00 **Concluding remarks**

17:00-18:30 **Poster removal**

19:00-22:00 ***Vulpes lagopus* banquet at *Les Complices***

22:00- **Bar (pay-your-own) at *Les Complices***

Sunday 15 October

09:00-17:30 **Field trip at Parc National du Bic**

09:00 Bus leaves Hôtel Le Navigateur

17:30 Bus back to Hôtel Le Navigateur

Abstracts

Session I

Fennoscandian Arctic and Yamal

On the edge: The Arctic fox in the Fennoscandian Arctic

Rolf A. Ims and Dorothee Ehrich

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In Fennoscandia, tundra habitats are widely distributed from 59 to 71°N, but of which only the northeastern edge (at 70-71°N) is proper arctic, while the rest is alpine tundra. Until a century ago, the Arctic fox was common in both alpine and arctic Fennoscandia, but the latter appeared to be a stronghold for the species with presence of both the coastal and the lemming ecotype. Presently however, the situation is quite the opposite; the arctic fox is on the edge of extinction in arctic Fennoscandia, while it recently has been increasing in the alpine tundra further south. We propose that the Norwegian lemming (the most important prey species) is more severely impacted by climate warming in coastal low-altitude arctic tundra than in continental high-altitude alpine tundra. Moreover, the red fox (the most important natural enemy) has probably become most subsidized by anthropogenic food sources in the Fennoscandian Arctic. Less arctic sea ice may also have reduced the connectivity to large arctic fox source populations in the Russian Arctic. We outline plans for research and management actions that may shed more light into these factors that appear to drive the arctic fox towards the edge in Arctic Fennoscandia.

Rolf A. Ims, rolf.ims@uit.no

Vole abundance and reindeer carcasses determine breeding activity of arctic foxes in low arctic Yamal, Russia

Dorothee Ehrich[1], Maite Cerezo[1], Anna Y. Rodnikova[2], Natalya A. Sokolova[3,4], Eva Fuglei[5], Victor G. Shtro[3] and Aleksandr A. Sokolov[3,4]

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[3] Arctic Research Station of Institute of Plant and Animal Ecology, Ural Branch, Russian Academy of Sciences, Labytnangi, Russia
[4]Arctic Research Center of Yamal Nenets Autonomous District, Salekhard, Russia
[5] Norwegian Polar Institute, Fram Centre, Tromsø, Norway

Arctic foxes are critically endangered in subarctic Fennoscandia, where a fading out of the characteristic lemming cycles and competition with abundant red foxes have been identified as main threats. We studied an arctic fox population at the Erkuta Tundra Monitoring site in low arctic Yamal (Russia) in order to determine which resources support breeding activity in this population. At Erkuta, lemmings have been rare during the last 15 years and red foxes are nearly absent, creating an interesting contrast to the situation in Fennoscandia. Arctic foxes were breeding in nine of the ten years of the study. The number of active dens was on average 2.6 (range: 0 – 6) per 100 km^2 and increased with small rodent abundance. It was also higher after winters with many reindeer carcasses, which occurred when mortality was unusually high due to icy pastures following rain-on-snow events. Average litter size was 5.2 (SD = 2.1). Scat dissection suggested that small rodents (mostly *Microtus* spp.) were the most important prey category. Prey remains at dens show that birds, notably waterfowl, were also an important resource in summer. The arctic fox in southern Yamal, which is part of a species-rich low arctic food web, seems at present able to cope with a state shift of the small rodent community from high amplitude cyclicity with lemming dominated peaks, to a vole community with low amplitude fluctuations. Only continued ecosystem-based monitoring will reveal their fate in a changing tundra ecosystem.

Dorothee Ehrich, Dorothee.ehrich@uit.no

Arctic foxes dominate the predator guild in low arctic Yamal, Russia

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In the low Arctic, the expansion of boreal generalist predators is a trend of change often attributed to increased availability of anthropogenic subsidies, which has possible cascading effects on other species both through predation on for instance ground nesting birds, or through competition with native arctic species. We monitored the predator guild in late winter at Erkuta long-term monitoring site in southern Yamal peninsula (68,2 N) since 2008 to assess the importance of different predator species and suggest possible interactions among them. Every year, 9 cameras baited with reindeer remains were deployed from late February to mid-late April. Cameras were placed in a line from the seashore inland. Pictures were taken every 5 or 10 min resulting in 20 000 – 116 000 pictures per year. The most numerous species recorded were arctic foxes, red foxes, wolverines, crows, ravens and magpies. Preliminary analysis showed that the proportion of days with records of arctic foxes were declining, whereas the appearance of red fox, wolverine and raven at the camera stations increased. Magpies appeared only during the last years of survey. We did not detect any signs of avoidance between different species, but observed series of pictures where arctic fox, red fox and wolverine used the same bait shortly after each other. At present, arctic foxes are still the most numerous predator registered at our camera stations, but our results indicate an ongoing trend of increase of subarctic and boreal generalist predators.

Aleksandr Sokolov, sokhol@yandex.ru

What resources subsidize arctic fox breeding in Sabetta, high arctic Yamal (Russia)?

Natalia A. Sokolova[1,2], Dorothee Ehrich[3], Ivan A. Fufachev[1] and Aleksandr A. Sokolov[1,2]

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[2]Arctic Research Center of Yamal-Nenets Autonomous District, Salekhard, Russia
[3]University of Tromsø – The Arctic University of Norway, Department of Arctic and Marine Biology, Tromsø, Norway

Arctic fox is the most numerous terrestrial predator in the north of Yamal Peninsula, but since the 1980s, no data exist about the population in this area, where major industrial development projects are being realized in recent years. We monitored the breeding activity of arctic foxes in Sabetta, which is located on the border between the low and high arctic (71°N). In this mainland tundra area, we expected to find typical lemming foxes increasing their breeding activity in accordance with lemming density. We surveyed from 24 (2014) to 31 (2017) dens each year. Automatic cameras were used to confirm breeding and determine litter size. The number of active dens varied from 1.5 to 9.6 per 100 km^2, and litter size varied from 1 to 15 and was on average 6.3. In 2014-2016 the number of active dens and litter size of arctic foxes varied in accordance with the abundance of small rodents (lemmings *Dicrostonyx torquatus* and *Lemmus sibiricus*, but also *Microtus* voles). However, in 2017, reproductive activity was surprisingly high despite low abundance of small rodents. This observation suggests the availability of considerable amounts of subsidies. We discuss the potential role of human waste from the growing settlement of Sabetta, as well as the access to marine subsidies such as seal carcasses or inland carrion such as reindeer carcasses. Detailed investigations of the diet of these arctic foxes in their specific ecosystem context will be necessary to determine the importance of these different resources.

Natalia Sokolova, nasokolova@yandex.ru

Session II

North America

Top-down regulation of lemmings by Arctic foxes and other predators: observations and experiments on Bylot Island

Dominique Fauteux[1], Gilles Gauthier[1], Rudy Boonstra[2], Rupert Palme[3] and Dominique Berteaux[4]

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[3]Institute of Biochemistry, Department of Natural Sciences, University of Veterinary Medicine, A-1210 Vienna, Austria.
[4]Canada Research Chair on Northern Biodiversity and Centre d'études nordiques, Université du Québec à Rimouski, 300 Allée des Ursulines, Rimouski, QC, Canada

Lemmings are generally considered key herbivores of the Arctic because they provide food for both mammalian (arctic fox, ermines) and avian (snowy owls, long-tailed jaegers) predators and, in some areas, can have dramatic effects on the tundra vegetation. Assessing their regular population fluctuations is of primary importance to understand demographics of Arctic predators due to very strong seasonal trophic interactions. We present our data from a long-term summer live-trapping and winter nest monitoring of brown lemmings (2004-2017) conducted on Bylot Island and discuss the relationship between their population cycles and their predators. We present the most recent results from an ongoing (since 2013) Before-After Control-Impact experiment to reduce predation in a 9 ha area. In contrast with some Greenlandic and Fennoscandian populations, our results indicate that brown lemmings of the Canadian high Arctic did not experience collapse of cycles. Our works also support strong top-down regulation of lemmings that prevent them from reaching densities high enough to cause food shortage. We suggest that the high inter-seasonal mobility of Arctic predators is responsible for the top-down control of small herbivores in the relatively unproductive High Arctic tundra.

Dominique Fauteux, dominique.fauteux.1@ulaval.ca

Are demographic parameters of adult Arctic foxes resource-dependent?

Clément Chevallier[1], Dominique Berteaux[1] and Gilles Gauthier[2]

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Predator population dynamics are highly impacted by prey availability. Many studies showed effects of food intake on reproduction, but due to difficulties of monitoring simultaneously prey and predator populations, the influence of prey abundance on survival is still unclear. Here, we investigate the effects of spatial and temporal heterogeneity in prey abundance on the adult survival and reproduction of a top arctic predator. We used a 13-years capture-mark-recapture database on an intensively monitored Arctic fox population in the Canadian High Arctic. We estimated survival and reproduction rates for adults with a multi-event approach. Using dummies occasions, we used multisource encounters data in a single analysis. Our results confirm a strong influence of both spatial and temporal prey abundances on reproduction rate. However, survival rate variability appears slightly explained by resources heterogeneity.

Clément Chevallier, chevallier.clement@gmail.com

Fine-scale genetic structure of the arctic fox population of Bylot Island (Nunavut, Canada)

Sandra Lai[1], Adrien Quiles[2], Josie Lambourdière[3], Dominique Berteaux[1] and Aude Lalis[2]

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The arctic fox (*Vulpes lagopus*) is a circumpolar species inhabiting all accessible Arctic tundra habitats. The species forms a panmictic population over areas connected by the sea ice, but recently, kin clustering and population differentiation were detected even in regions where sea ice was present (Svalbard and Alaska). The purpose of this study was to examine the fine-scale genetic structure of a population in the High Arctic using a robust panel of highly polymorphic microsatellites. We analyzed the genotypes of 210 individuals from Bylot Island (73°N, 80°W), Nunavut, Canada, using 15 microsatellite loci. No pattern of isolation-by-distance was detected in our 600-km^2 study area, but a spatial principal component analysis (sPCA) revealed the presence of genetic subdivisions. Overall, the two first sPCA axes together revealed two spatially distinct genetic clusters corresponding to the northern and southern parts of the study area, plus another subdivision within each of these two clusters. The north-south genetic differentiation in the population partly matched the distribution of a snow goose nesting colony, which could reflect a preference for settling into familiar ecological environments (habitat imprinting). Secondary clusters may result from higher-order social structures (neighbourhoods) that use landscape features such as rivers to delimit their borders. The cryptic genetic subdivisions found in our study population may highlight ecological processes that deserve further investigations in arctic foxes at larger, regional spatial scales. Fine-scale genetic analyses at a high genetic resolution will improve our understanding of the ecological factors inducing genetic differentiation in populations.

Sandra Lai, laisandra@gmail.com

Are arctic fox reproductive dens vulnerable to climate change in the Canadian High Arctic?

Florence Lapierre Poulin[1], Daniel Fortier[2] and Dominique Berteaux[1]

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Climate change has an impact on numerous faunal species not only through biological means, but also physical processes. Rising rates and magnitudes of warming and other changes in the climate system increase the risk of severe alterations to essential habitats, especially in the Arctic. One species likely to be affected by these changes is the arctic fox (*Vulpes lagopus*), because of the close bond it maintains with its habitat. In fact, arctic foxes use the same den year after year to raise their young, which is a crucial step of their life cycle. The increasing frequency of geohazards like mass movements, thaw settlement, and thermal erosion are a threat for the stability of these dens. On Bylot Island (NU, Canada), we developed a simple vulnerability index to these hazards for arctic fox dens, based on observations both on the field and from aerial photographs. Of the 102 dens studied, 17% were classified as highly vulnerable while the majority (66%) was only slightly vulnerable. There was no significant impact of vulnerability on dens' probability of use for reproductive purposes. This study provides insights into the geomorphological response to climate-related geohazards affecting arctic fox ecology. Our method can eventually be used by other similar study sites to support stakeholders when facing major conservation issues resulting from global change.

Florence Lapierre Poulin, florence.lapierre.poulin@hotmail.com

Session III

North America

Satellite tracking of Arctic foxes on the Canadian Arctic sea ice

Dominique Berteaux

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The Arctic fox has long been known to forage on the sea ice, but until recently formidable logistic challenges prevented any study of its winter ecology. We asked when, how and why Arctic foxes use the sea ice. We tracked (Argos) >130 individuals year-round during 10 years around North Baffin Island, Canada. Individuals could cover thousands of km on the sea ice during winter, at high and sustained travel rates reaching 90 km/day. They could detect carrion from unexpected long distances (> 10 km), and they sometimes met at hotspots of fox activity gathering up to 12 individuals. However, despite these strong movement abilities, most individuals retained their tundra territory during winter, making short commuting trips to the sea ice rather than engaging in long-distance resource tracking. Although foxes live in pairs, extraterritorial excursions of pair members were not synchronized and they foraged independently when on the sea ice. This wealth of new data generated by satellite tracking has opened many original research avenues at the individual, population and ecosystem levels. We now intend to use GPS tracking and accelerometers to fine tune our understanding of the predator-prey interactions in which Arctic foxes are involved.

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Arctic foxes facilitate trophic and non-trophic interactions at the edge of the Arctic

James D. Roth

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Interactions between predators and their prey are strongly affected by alternative prey or other predators, but non-trophic mechanisms of interaction can also influence species distributions and abundances in ways that may be counterintuitive. As the main terrestrial predator throughout the Arctic, Arctic foxes impact survival and reproduction of their prey (lemmings, migratory birds in summer, and seals on the sea ice in winter) and also facilitate indirect effects of these prey on each other. Arctic foxes also impact other species by modifying the physical environment. Through concentrating nutrients on dens, Arctic foxes enhance soil nutrients and increase plant productivity, which may attract lemmings and other herbivores. We are investigating indirect interactions involving Arctic foxes and their prey near Churchill, Manitoba, on the west edge of Hudson Bay, where boreal forest transitions to Arctic tundra. This site is near the southern edge of many Arctic species' distributions, where the impact of climate change is likely to be large. Climate change has been implicated in dampened lemming cycles, decreased seal availability, and expansion of mammalian predator ranges in the Arctic, all of which could strongly affect tundra predators and disrupt Arctic food webs. Understanding indirect interactions among fox and prey populations will help predict the wider consequences of climate change, and examining the importance of fox den sites for other organisms will reveal the broader impact of changes in fox populations at the southern edge of their distribution on Arctic biodiversity.

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Arctic fox rabies in a warming Canadian Arctic, 1953-2014: from surveillance to ecological mechanisms

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Arctic fox rabies is an ongoing public health concern for northern communities. Through various mechanisms, including effects on population dynamics of different species, climate change is expected to modify the ecology of arctic fox rabies. This study provides a descriptive overview of the spatio-temporal patterns in rabies infection across the Canadian Arctic. Secondly, it explores possible mechanisms driving the onset of rabies outbreaks in the fox populations, such as fox density as influenced by lemming population dynamics, and climatic factors. In Canada, the Canadian Food Inspection Agency is responsible for rabies diagnostic testing of animals suspected to be rabid when there was potential human or domestic animal disease exposure. We present an analysis of rabies cases collected through this surveillance system in Yukon, Northwest Territories, Nunavut, Nunavik and Labrador from 1953 to 2014. This study provides the most complete portrait to date of rabies across the Canadian Arctic. We report on large space-time transmission dynamics, epidemiological links between arctic foxes, red foxes, and dogs, with synchrony in outbreaks occurring in these species, and disease connectivity between Nunavik and Labrador. Results suggest that fox density and climate, via temperature, precipitation, snow depth, and sea ice extent, are important factors driving rabies transmission dynamics. We discuss implications for forecasting rabies dynamics in northern ecosystems given ongoing climate warming.

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Modeling rabies transmission in the arctic fox: toward a comprehensive picture of risk exposure for dogs and people in the Canadian Arctic

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Rabies is a major issue for human and animal health in the Arctic, yet little is known about its epidemiology. In particular, how the rabies virus persists in low-density and highly variable populations of Arctic fox (*Vulpes lagopus*), the primary reservoir host for Arctic rabies, is an ongoing debate. In this context, a mathematical modeling approach can be useful to understand the complex dynamics of risk of rabies exposure at the interface between wildlife, dogs, and people of communities in the Canadian Arctic. We present two modelling approaches to capture different aspects of rabies dynamics in the Arctic: a Susceptible-Exposed-Infected-Resistant (SEIR) epidemiological model exploring temporal dynamics and a spatially explicit individual-based model to capture the effects of individual behavior and geography on spatiotemporal dynamics. We illustrate the types of questions that can be answered using these modelling frameworks with the results from the SEIR model of rabies transmission, including the potential for transmission to and within a sympatric population of red foxes, another rabies host that is increasingly present in the Arctic. Our work suggests that disruption of prey cycles and increasing interactions between Arctic and red foxes due to climate change and northern development may alter the epidemiology of Arctic rabies. Ultimately, these models provide new tools to predict how the transmission and impact of disease on animal and human health are likely to change with rapid and accelerating climate change.

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Transmission dynamics of *Toxoplasma gondii* in Arctic foxes (*Vulpes lagopus*): A long term mark recapture serological study

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Transmission dynamics of *Toxoplasma gondii*, a parasite of importance for wildlife and human health, is enigmatic above the treeline in the Arctic, where felid definitive hosts are rare. Through a multi-year mark-recapture study (2011-2017), we conducted serosurveillance to investigate transmission of *T. gondii* in Arctic foxes (*Vulpes lagopus*) in the Karrak Lake region, Nunavut, Canada. Sera from adult foxes and fox pups were tested via two serological methods, Indirect Fluorescent Antibody Test (IFAT) and Modified Agglutination Test (MAT) for antibodies to *T. gondii*. Mature foxes were more likely to be exposed (seroconvert) than young foxes. Mid-aged foxes (2-4 years) had the highest rate of seropositivity. In one older fox that was initially seropositive, antibodies were not detected in a subsequent recapture, implying that *T. gondii* antibodies might fade over time. This research demonstrated seropositive pups on emergence from the den, suggesting that vertical transmission might play a role in exposure to *T. gondii* in the Karrak Lake ecosystem. Some of these pups were born of mothers that were seropositive in previous years, suggesting that vertical transmission might not be limited to litters of mothers exposed to *T. gondii* for the first time during pregnancy. This work gives us a better understanding of how foxes are exposed to *T. gondii*, the dynamics of antibody persistence, and how the parasite maintains itself in a terrestrial High Arctic ecosystem in the absence of felid definitive hosts.

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Population status of the endemic Pribilof Fox *Alopex lagopus pribilofensis*: Continued decline amidst escalating threats is cause for concern

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The Pribilof Fox, *Alopex lagopus pribilofensis,* is a subspecies of arctic fox endemic to Alaska's Pribilof Islands. Historically, Pribilof foxes numbered in the thousands. Due to concerns regarding population decline, in 1990, I initiated island-wide surveys and monitored reproductive effort at 98 dens on St. Paul Island to assess population status and documented sources of mortality and potential threats to fox survival. In 1990, the total fox population on St. Paul Island was estimated at 487 adults. Den occupancy was 91% (87 of 98) and 55 litters were produced. In 1991, den occupancy was 86% (83 of 97) and only 34 litters were produced. Subsequent surveys have documented continued decline in population size in the face of escalating threats. In 2015, St. Paul Island's fox population was estimated at <150 adults. Two main causes of fox population decline appear to be reduction in natural food resources and direct persecution by humans. Additional factors possibly inhibiting population recovery include reduction in the frequency of sea ice events resulting in increased genetic isolation, and exposure to pathogens from domestic pets. High levels of environmental contaminants also have been found in Pribilof fox tissues. A recently described disease suspected to be a bacterial-induced polyarthritis characterized by a severe chronic active polyarthritis and leukocytoclastic vasculitis has been documented. This condition usually results in death of the fox. Barring intervention aimed at addressing the causes of population decline, Pribilof foxes on St. Paul Island are at risk of extinction within the next 25 years.

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Session IV

Svalbard and Greenland

Impact of harvesting on demographic and genetic structure of the Svalbard arctic fox population

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Arctic foxes have been harvested in Svalbard for several hundred years. Today the hunting season lasts from 1 November to 15 March. At the Austfjordnes trapping station, a low-intensity harvest that took few animals was carried out from the season 2000-2001 and up to 2008. In the 2008-2009 season, in contrast, hunting intensified, resulting in a large offtake that continued over the next two seasons. This gave us an opportunity to do an observational study with a "before – after" comparison in this area.

We found significant effects of harvesting on the demographic structure of the arctic fox population. The proportion of young foxes rose because of harvesting, with the increase greater for females than for males. The most important effect was that the proportion of older females in the population was significantly lower in harvested populations, which may have consequences for the population's growth potential. There were no clear effect of harvesting on the genetic composition of the fox population as a whole. However, when we examined the sexes separately, we found a greater degree of genetic variation among males than among females in the years immediately following harvesting. This indicates that it is primarily the immigration of young males that rebuilds population numbers after harvesting.

To date, our population monitoring data show no consistent declining trend in population size. The results of our genetic analyses suggest that the immigration that occurs following hunting compensates for the offtake, but it is also possible that other compensatory mechanisms counteract the harvest.

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An integrated approach for modeling environmental effects on population dynamics of the Arctic Fox in Svalbard

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Predicting the responses of animal populations to climate change requires linking population models to variation in underlying demographic rates. This, in turn, relies on the availability of long time series of individual-based data. In the absence of continuous high quality data, Integrated Population Models (IPMs) become very valuable. They combine different sources of data into a joint likelihood, allowing precise estimation of demographic rates that could not be estimated from single datasets. We use this integrated approach to build an age-structured population model for the Arctic fox in Svalbard by combining 20-year time-series of harvest data, carcass autopsies and den surveys with sporadic data from shorter mark-recapture and telemetry studies. By further modeling demographic rates as functions of environmental variables, our population model becomes a tool to understand the drivers of past population dynamics and to make predictions about how Arctic foxes will respond to future changes in climate and harvesting regimes.

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The responses of arctic foxes to lemming cycles in North East Greenland as assessed through a 30-year long term monitoring

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The Arctic Fox occurs throughout the entire fringe of coastal Tundra in Greenland, from 60° to 83°N. In the high-Arctic lowlands of North and North-East Greenland, its range overlaps with the Collared Lemming, both species being major components of one of the most simple vertebrate terrestrial communities.
Our ongoing long term study of the lemming cycles in relation to their predators' responses (1988-2017, Traill Island, 72,5°N-24°W), provides unique insights on how the Arctic Fox respond to its main and fluctuating prey.
In this part of its breeding range, the Arctic Fox has to cope with high amplitude annual changes in the availability of lemmings and with limited availability (both in diversity and abundance) of alternate prey, most being accessible only seasonally.
Although it exhibits a generalist (type III) functional response to changes in lemming densities, the Arctic Fox is most strongly linked to the lemming population dynamics during the low phase of their 4-year cycle, with lemmings accounting for 50 % of its diet even at densities as low as 0.1 ind./ha.
Lemming dynamics in this site featured contrasting patterns including 4 years cycles in the first half of the monitoring (1988-2002) followed afterwards by a fading of the cycles, with lemmings since then no longer achieving comparable peak densities (of up to 15 ind/ha). As assessed by the monitoring of 7 to 8 dens (area of 75 km2) foxes responded by successful breeding in 9 out of 15 years during the 3 first cycles. Afterwards, they still reacted to more temporary recoveries of the lemming population (densities above 1 ind/ha) by successful breeding, but as a whole, the number of weaned young probably declined.
Comparisons with responses reported from other parts of its breeding range also provide interesting insights into the plasticity of the Arctic Fox and its ability to cope with changing availability of food resources.

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Space use of Arctic fox in Greenland

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In Greenland, the Arctic Fox is a key predator found across all terrestrial biotopes. Its population dynamics have been documented for decades in some regions of this country but with the exception of some radio tracking studies monitoring a limited number of individuals over a few weeks, virtually nothing is known about its space use at different spatial and temporal scales.

During the summer 2016 we deployed nine Argos satellite PTT on breeding adults in three different study areas (3 per site including one pair), all located in the N & E Greenland National Park where they occur with the Collared Lemming and three other important terrestrial predators: Snowy Owls, Stoats and Long-tailed Skuas (all four species being missing in W, S and SE Greenland).

As expected from the extensive satellite tracking studies in Canada (Bylot Island), most foxes remained territorial during the entire winter and only travelled short distances (<100km) for shorter periods (a few days). However, contrary to what has been documented in Canada during some winters, the Greenland foxes made very little use of the nearby sea ice. We also discuss between year (two summers) and between-sites differences in space use, likely resulting from annual and site-specific differences in food abundance and availability.

During the summer 2017, we deployed GPS collars on four adult foxes (2 ind.*2 sites). Although technical problems prevented us to monitor these foxes for the entire summer, preliminary results from this pilot study are promising and open many new perspectives for future work.

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Session V

Scandinavia

The arctic fox conservation in Scandinavia – management and collaboration

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The arctic fox is classified as endangered in Sweden and critically endangered in Norway. In the 19th Century, it was a common species on the mountain tundra, but in response to intensive harvesting, the population declined severely at the end of the 19th century. The arctic fox was protected by Swedish law in 1928 and Norwegian law in 1930, but despite this, the population remains small. In 2015, Sweden and Norway signed an agreement with the aim of strengthen the collaboration for arctic fox conservation.

During 1998–2008, conservation actions in the form of inventories, red fox culling and supplementary feeding was implemented in Sweden and Finland. During 2008–2012, red fox removal and supplementary feeding was financed through the Swedish action plan. In Norway, conservation actions started in 2004, financed by Norwegian Environment Agency. Since then, a combination of action has been implemented in the different subpopulations, including captive breeding and release of juveniles, supplementary feeding and red fox control. Within the EU-Interreg project “Felles Fjellrev” (2010–2013) increased actions were conducted in the county of Jämtland as well as Nord- and Sør-Trøndelag, specifically focusing on smaller mountain areas located between the core areas.

To reach a viable population in Scandinavia, Norwegian Environment Agency and Swedish environmental protection agency made an action plan (2017 – 2021). The vision of this plan is to reach a viable Scandinavian arctic fox population without need for further conservation actions. The action plan emphasizes the importance of continuing the central actions of supplementary feeding and red fox control.

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Status and conservation goals for the critically endangered Arctic fox in Scandinavia. When is the mission completed?

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The arctic fox is listed as critically endangered, despite 80 years of protection in Scandinavia. Following intensive action programs over the last 15 years, the population has increased from less than 50 to more than 250 reproductive individuals. Sub-populations are reestablished and the connectivity is about to be restored. Actions comprised red fox culling, supplemental feeding and release of captive breed foxes.

Long lasting conservation programs need goals, to be targeted and effective, to keep priority for funding within environmental agencies, as well as legitimacy in the society. Although the Scandinavian arctic fox population has increased, the population is still far from being viable. We have calculated the potential carrying capacity of different subpopulations based on landscape productivity and the Nature Index methodology. Restoring populations is by far most effective through release of captive breed foxes. Subpopulations with released cubs, also have the highest growth rate compared to subpopulations that achieved supplemental feeding and/or red fox culling. But it is also the most intensive and costly conservation measure, that need to be effectively used.

In this study we use distance from carrying capacity and connectivity/degree of isolation, to target the need for actions and define conservation goals at the level of sub-populations. Intensive actions will likely be needed over 15-20 years more, to achieve a long lasting viable population of arctic foxes in Scandinavia.

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Genetic consequences of conservation management: the case of the arctic fox (*Vulpes lagopus*) in Scandinavia

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The Arctic fox (*Vulpes lagopus*) population in Fennoscandia experienced a drastic demographic and genetic bottleneck in the early 20th century as a result of high hunting pressure. In 2000, despite almost 70 years of protection, the population showed no signs of recovery. The small and fragmented nature of the population, making it highly susceptible to the risks of inbreeding, genetic drift, and Allee effects.

Beginning in 1998 a number of conservation measures were implemented in order to mitigate the population decline and facilitate re-establishment. The positive demographic impact of these strategies has been confirmed, and the population has more than doubled in size during the past decade. This study compares microsatellite data across 8 loci in Scandinavian arctic fox samples collected between 2008 and 2015 in three core populations and five stepping stone areas to investigate whether the recent demographic success of the mid-Scandinavian arctic fox population has been complemented by changes in genetic diversity, genetic differentiation, and connectivity between subpopulations.

The results suggest that genetic diversity at the subpopulation level has increased substantially during the last decade, while genetic differentiation among populations has decreased. Patterns of dispersal complement these findings, highlighting the important role of immigration in ensuring subpopulation and metapopulation persistence. Indeed, the evidence of increased genetic diversity and connectivity during the last decade indicate a restoration of metapopulation dynamics in the Scandinavian arctic fox population and an increase in the long-term viability of the species.

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The Swedish arctic fox – a model system for the extinction vortex?

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Central themes in the field of conservation genetics are the small population paradigm and the extinction vortex model. According to these, the decline of a small population accelerates through an interplay between demographic and genetic processes. The Swedish arctic fox went through a population bottleneck in the 19th century and was on the verge of extinction in the 1990s. One sub-population was re-founded by five individuals in the early 2000s, but is exposed to inbreeding depression and genetic drift though isolation. Inbreeding influences fundamental fitness traits like juvenile survival, reproduction and longevity. Despite this, the population has, in contrary to the theoretical expectations, gone through a four-fold increase in response to conservation actions. In this talk, genetic and recently derived genomic data from this sub-population is used to evaluate the extinction vortex model in relation to the demographic population development. Based on this, the support for the extinction vortex model and alternative processes (i.e. balancing selection and inbreeding avoidance) acting on population dynamics as well as the role of the arctic fox as a potential model system for conservation genetics are emphasized.

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Genetic rescue in an inbred arctic fox population

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Isolation of small populations can reduce fitness through inbreeding depression and impede population growth. Outcrossing with only a few unrelated individuals can increase the demographic and genetic viability substantially, but few studies have documented such genetic rescue in natural populations. We investigate the effects of immigration in a subpopulation of the endangered Scandinavian arctic fox (*Vulpes lagopus*), founded by five individuals and isolated for nine years at an extremely small population size. Based on a long-term pedigree (105 litters, 541 individuals) combined with individual fitness traits, we found evidence for genetic rescue. Natural immigration and gene flow of three outbred males in 2010 resulted in a reduction in population average inbreeding coefficient (f), from 0.14 to 0.08 in 2015. Genetic rescue was further supported by 1.9 times higher juvenile survival and 1.3 times higher breeding success in immigrant first generation offspring compared to inbred offspring. Five years after immigration, the population has almost doubled in size and allelic richness has increased by 37%. This is one of few studies that has documented genetic rescue in a natural mammal population suffering from inbreeding depression and contributes to a growing body of data demonstrating the vital connection between genetics and individual fitness.

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Demographic and genetic rescue in an arctic fox (*Vulpes lagopus*) subpopulation

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Living in a small population could mean a lot of problems for both population and individual level conservation. To prevent both low numbers and inbreeding the population needs immigrants. Hence an immigrant can be said to rescue a declining population both numeric (demographic support) and genetic if they manage to reproduce successfully. To secure and facilitate genetic diversity and recolonization of former arctic fox habitats the Norwegian Institute for Nature Research (NINA) started a captive breeding program in 2005. Each year juveniles are released in important areas within Norway but sometimes a few of the released animals immigrate to a Swedish arctic fox population. At late, genetic and observational data have revealed that immigrants from the Norwegian breeding program have migrated into the Swedish Vindelfjällen/Junkeren-population. From this population demographic as well as genetic data have been collected for several years. The study has examined how the influx of immigrants influences both demography and genetic variation and also how many immigrants that have established in the area. Are we seeing both a numerical and a genetic rescue?

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Session VI

Scandinavia

Conservation biology of the arctic fox – effects of sarcoptic mange

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Arctic foxes have strong relationships with many other species. The most important food for arctic fox in mainland areas are different species of lemmings. Most lemming populations go through cyclic phases and the arctic fox biology is closely related to these cycles. Therefore, with fading population cycles for lemmings, there are strong consequences for arctic fox populations. There are also complicated relationships with the red fox with both competition and intra guild predation, and this is also mediated by the lemming cycle. A third group of species interactions are with diseases and parasites. Sarcoptic mange is a parasite that can reproduce in fox and wolf species with for example drastic population declines in red foxes. In one of the Swedish subpopulations we have had two outbreaks of sarcoptic mange. In 2013 we found mange at 10 of 22 inventoried dens. We treated the dens with baits injected with Dectomax at all inhabited den sites every third week during the spring and summer. After three months the mange had spread to 19 of 23 inhabited dens. We repeated the treatment 2014 after new cases of mange with zero cases 2015-16. However, the mange returned at three of the same dens 2017 and we used a similar treatment again. The mange was spread from diseased red foxes and this was also mediated by the lemming cycle. These two outbreaks of mange have severely threatened this subpopulation with at least a 50% decline.

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Seasonal camouflage and climate change – Phenological mismatch in the Arctic fox?

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Camouflage mismatch may occur among seasonally color molting animals when snow duration and winter white coat phase are out of sync. This type of phenological mismatch is expected to increase in the future, as snow duration will continue to shorten under anthropogenic climate change. The arctic fox is a color molting species naturally occurring in two color morphs – blue and white. Only the white color morph has a true seasonal color molt and can experience the highly conspicuous 'white-on-brown' background mismatch. Contrastively, because the blue color morph stays dark year round and is mismatched against the white background all winter, less snow will decrease its mismatch. Using remote camera traps, we monitored color molts and mismatch in two Swedish polymorphic subpopulations of arctic foxes. We described high inter- and intra-population variation in molt phenology during one spring and two fall seasons and found an effect of climate, sex and age on the molt phenology. Next, we quantified mismatch frequency in both color morphs and showed that, currently, both experience mismatch, but its timing and severity differs between morphs. Climate change will likely result in increasing mismatch in the white morph, unless adaptive changes in molt phenology occur.

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Litter sizes and territory quality – Is there a landscape effect on reproductive investment in lemming foxes?

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Reproductive output – the number and quality of juveniles produced – depends on the resources the reproducing organism is able to allocate. In territorial animals the general status of the mother depends on food availability and is thus mediated by territory quality. Variation in litter size could therefore be expected to reflect habitat quality in species with variable litter size. The lemming ecotype of the arctic fox shows remarkable variation in litter sizes, spanning from 1 to ca 20 cubs, making it an ideal study species to investigate how recourse availability affects and interacts with reproductive investment. The connection between small rodent abundance and litter size is well established. However, since prey is not evenly distributed in the landscape, densities could be expected to reflect local differences in primary productivity. In this study, we assessed primary productivity using satellite and aerial photos as an indicator of habitat quality. Together with long term data of litter size from the Swedish Arctic fox population we investigated if there was a relationship between territory quality, and reproductive output during the small rodent cycle.

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Parent personality influences juvenile behaviour and mortality in Swedish arctic foxes

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Life history theory predicts that individuals should adjust their risk-taking behaviour to their expected future fitness. Understanding consequences of such individual variation within a spectrum of a behavioural trait is crucial in explaining potential trade-offs between different traits and in predicting future dynamics in changing environments. Here we studied individuals in a wild arctic fox population to explore if 1) individual variation in risk-taking behaviours of adult arctic foxes and in stress-dealing behaviours of their juveniles exist and are consistent over time to verify the existence of personality traits; 2) those behavioural traits in adults and juveniles are correlated; 3) they can explain a fitness-related component (i.e., juvenile mortality rate). We presented simple field experiments extracting behavioural traits by observing adult reactions toward approaching observers, and juvenile trapped behaviours. We found consistent individual variation ('personality') of adults in their vigilance and boldness level, and inconsistent juvenile behavioural traits categorized as investigating, passive, escaping. Bolder adults had more investigating and less passive juveniles. Lastly, juveniles with bolder parents and with more investigating and less passive behavioural trait had significantly lower mortality rates. This shows that interactions between parent personality and juvenile behavioural traits affect a fitness-related component in the life history of individuals. This provided the basic for understanding personality-driven dynamics of populations under fluctuating environments and different selection pressures, and highlights the need for further studying fitness consequences and trade-offs between different personality and behaviour traits over a longer period.

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Mutual relationships between tourism and arctic fox conservation

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There are both positive and negative impacts on wildlife associated with wildlife tourism. In Sweden, the endangered Arctic fox is subject to a growing tourist interest, with some tour operators offering guided Arctic fox safari tours. To investigate the effects of the tourism and the tours on the Arctic fox, five dens with various levels of disturbance from tourism was monitored with automatic wildlife cameras. The results show that the tourism did have an effect on the activity and behavior of individual arctic foxes, while no negative impact was observed on their distribution, breeding success or survival rate. Further, the results indicated that Arctic fox predators and competitors might avoid areas with human disturbance, providing a refuge for the Arctic fox.

A survey about conservation knowledge and awareness was also distributed to five separate groups of visitors in the region. The results revealed that knowledge about the status of Arctic foxes and awareness of the behavioral guidelines for Arctic fox encounters improved after participation in a safari tour, which along with economic contributions are important positive effects of wildlife tourism.

For the future study of human impact on wildlife, we propose a schematic model summarizing the diverse ways in which wildlife tourism affects wildlife and their relative importance for conservation. The Arctic fox population in Sweden is small and sensitive to disturbance, but the positive impacts of Arctic fox tourism seem to compensate for the negative and contribute to their conservation under the current level of tourism pressure.

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Bringing the field to your phone

Sandra Jönsson

Communicator Felles Fjellrev editorial group

Communication, information and increased accessibility.
The Arctic fox is one of the most threatened mammals in Scandinavia. Hunted close to extinction a hundred years ago, there is now only one small breeding population left in the EU, sparsely spread in the Scandinavian mountains.

The Arctic fox is an animal not very well known by the public. For future management efforts, in order to restore the Arctic fox population in Scandinavia, it is important to convey knowledge about and interest in the Arctic fox. Communication with the public is therefore an important part of Felles Fjellrev.
We're bringing the field to your phone.
Social media streams are becoming people's primary source of information – an important platform to use and also a way for us to understand how people connect with nature. Even though back-packing in the Scandinavian mountains is increasing, a lot of people will never see the Scandinavian mountains – or the rare Arctic fox.
By using social media we can connect people with the Scandinavian mountains, the arctic fox, on-going research projects and the daily life and work in the field. This also provides people with the ability to connect with nature through their phones. Not only to increase public awareness about the Arctic fox but to become familiar with a faraway place. What we like we want to preserve.

Felles Fjellrev editorial group, by Sandra Jönsson, sandra.jonsson@wwf.se

Session VII

Scandinavia, Iceland and the rest of the world

Individual use of feeding stations – Who's eating all the food?

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In Norway, the arctic fox is listed as critically endangered, with a minimum population size of 108 individuals. The low population size and the collapse of rodent-cycles in several mountain areas are considered as two of the main threats to the arctic fox in Norway/Scandinavia. To increase the survival of both wild and captive bred and released foxes, supplementary feeding of arctic foxes was started in 2007, in the mountain are of Snøhetta, Norway. Supplementary feeding has been shown to have an effect on reproduction and social organization in arctic foxes. However, although the feeding stations have "open access", the use is expected to vary among individuals. This can be due to several factors, such as monopolizing of feeding resources by older or more dominant individuals, distance from the individual's home range to the feeding station, or variation in foraging skills and behavior. Knowledge about how and when individual foxes use the feeding stations may help us better understand the effects of supplementary feeding. In Snøhetta wild born cubs has been captured and marked with a pit-tag since 2010. In addition, 60 captive bred cubs have been released in Snøhetta in the period 2007-2011. Using a pit-tag reading system we are thereby able to monitor a large percentage of the individuals using the feeding stations. Preliminary data show that 85% of the foxes registered on a feeding station are two years or younger. This can point to a large number of floaters using the feeding stations.

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Survival of captive-bred and released versus wild-born Arctic foxes in Norway

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The Fennoscandian Arctic fox population was recently close to extinction, with an estimate of 35-85 adult foxes left in 1998. Several conservation actions have been implemented, including supplementary feeding, red fox culling, and captive breeding and reintroduction. The Norwegian captive breeding programme was established in its current form in 2005 and has since re-established extinct subpopulations and strengthened extant ones. To date, 320 captive-bred and released and >700 wild-born Arctic foxes descending from released foxes have been monitored in different mountain areas. Identifications of marked foxes are routinely collected using a combination of techniques, including direct observations and indirect observations from wildlife cameras, captures, DNA extracted from scats, and identification of individuals using microchips detected by specific readers. Using all identifications, 43% of released foxes survived until April 1st following the release. Released foxes had a significantly higher first year survival than wild-born foxes (DNA data only, 0.22 vs. 0.14, respectively, p = 0.020). Released foxes were generally in very good body condition at a time when wild foxes were already subsisting on their body fat reserves (mean weight: 3.99 ± 0.37 kg, *n*=250 *vs.* 3.59 ±0.70, *n*=34, respectively), indicating that released foxes probably did not suffer starvation during the harshest time of the year. Surprisingly, adult survival was also significantly higher for released compared to wild foxes (DNA data only, 0.15 vs. 0.09, respectively, p = 0.047). Further analysis will allow to better predict the potential for future contribution of captive breeding and reintroduction to the recovery of Arctic fox populations in Fennoscandia.

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Is there hope for the arctic fox in Finland?

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Due to excessive hunting in early 1900's, the Finnish arctic fox population declined. The species was protected in 1940, and after that the population stayed at moderate density until early 1980's, breeding reflecting vole/lemming cycles, but there was no recovery to old densities. Starting in mid 1980's, a new decline started, and this was associated with the expansion of the red fox into the alpine zone. The last breeding observation in NW Lapland took place in 1994 and N Lapland in 1996. Since then, there have been annually 5-15 observation of arctic foxes in N Lapland, probably dispersers from Sweden and Norway, but no breeding has been observed. Though, during last two winters, one or two pairs have been observed at the old breeding sites. We have mapped the old den sites of arctic foxes and the new excavations/den sites of red foxes in NW and N Lapland. The unfortunate fact for the arctic fox is that in Finnish Lapland almost all alpine habitats are at quite low altitudes, and within the present range of the red fox. We calculated the altitudinal range of dens sites of both species, and they overlap totally. In Finnish Lapland, where high mountains areas are missing, there are no high enough areas where the arctic fox could survive without the red fox expansion. Consequently, with the present altitudinal distribution of the red fox, the future of the arctic fox looks bleak though we could hope for some breeding efforts in good vole/lemming years.

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Home ranges and territoriality of island arctic foxes under abundant food conditions

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Food distribution and predation pressure are usually considered as the main factors of spatial behavior. We examined range use of arctic fox, an apex predator on Bering Island (North Pacific). The study was conducted in July - August 2014 and 2016 near the northern fur seals rookery. Thereby in summertime these foxes had an extraordinary abundant source of food (seal placentas and carcasses). Nine adult foxes (4 males and 5 females) from 3 breeding (2014) and 4 non-breeding (2016) family groups were equipped with GPS-collars which collected fixes every 5 *minutes.* Foxes were tracked during 12–30 days each. Home range size (N=7, number of family groups) was (Mean±SD) 48±29 (min-max: 19–90) ha by 99.5% Brownian bridge movement model (BBMM), 39±28 (14–81) ha by 95% fixed kernel and 79±47 (29–144) ha by MCP100. Size positively correlated with the distance between home range activity centers and the most populated seal breeding site. The BBMM home range borders of males and females from the same mated pairs were nearly identical. For foxes from adjacent family groups HR overlap was 12±11 (1–38) % by area and 8.7±12.7 (0.1–52.8) % by UD (7 families, N=24). Overlap for non-breeding groups has a tendency to exceed ones for breeding families. Obtained summer home ranges are ones of the smallest for the species. Though island syndrome could be the main factor, the abundance of food resources has also reduced home range size but not territoriality which was strengthened by presence of pups.

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Does it pay off to breed young? Demographic response to heavy hunting pressure during the breeding season

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In Iceland, the native Arctic fox is systematically killed, in order to reduce alleged damage on livestock. Hunting is conducted all year round in most regions, managed and practiced by authorities. During the past 250 years, foxhunting has also taken place at breeding dens in May to July. The potential effects of intensive den hunting on the demography of the local fox population is unknown. However, available data show surprisingly high proportion of one-year-old vixens killed as breeders on a den.

Physically, both sexes become mature in their first winter but breeding may not be an option until later. In order to have the chance to breed, the foxes need to not only be healthy and strong, but also have access to available territory. Den hunting activity removes a breeding couple from a territory and provides increased opportunities for all individuals to take part in breeding, even at young age.

One might assume that energy demanding gestation and lactation period should be hazardous for young and inexperienced females. It is therefore interesting to try to find out the cost of breeding at so young age. In order to do so, the survival rate was compared between young breeding and non-breeding females. The first result are surprising, as it appears that non-breeding females had lower survival than the young breeding females. Therefore, it looks like it pays off for young foxes to seek the opportunity and breed at young age. Most likely, it will maximize their reproductive output, but it might also be a lethal choice.

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Exploring different methods of visual storytelling to help communicate Arctic fox (*Vulpes lagopus*) research

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Communicating ongoing projects and research findings is an increasingly vital part of science, and I explore how to use different mediums of visual storytelling (mainly art and video) to relay that information to the public. Using past and future projects on Icelandic foxes as an example, I'll discuss different ways in which visual art has the potential to be a useful tool for engaging communities, raising awareness, and raising money. I emphasize the importance of finding a narrative thread within research, since adding story to visual art can make it all the more compelling to those not familiar with the subject matter. I will broaden this discussion to review potential narratives—e.g. adapting to global climate change—relevant to the entire species, focusing on how I might create visual art that would benefit the whole arctic fox research community. This talk is meant to encourage conversations about how best to visually communicate research, and whether or not art can assist in fostering international collaborations by generating similar interests between different communities.

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Session VIII

Methods and other species

FoxMask image analysis software, assisting ecologists in facing big data challenges

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Camera traps are an efficient data gathering method and, as such, are widely used by ecologists. They generate massive amounts of images, however, that are impossible to analyze by humans or with traditional processing application software. Efficiently analyzing such data requires the implementation of an analysis pipeline using an ETL (Extraction, Transformation and Loading) type method. We developed an automated image analysis software (named FoxMask) that sits in the "Transformation" component of ETL type method. FoxMask can efficiently detect animals on images, using background detection and foreground segmentation methods, as well as movement and an object size threshold to discriminate animals from noise. On 30 sets of 500 images, the software had a 92.6% rate of success in identifying images containing animals (here, arctic foxes). The software can be easily executed on cloud computing architectures, opening the possibility to run parallel analysis on multiple computers for mass data transformation. It is entirely based on open source technologies, making its usage and future collaborative development free from any licensing constraints. FoxMask represents a first step in an integrated solution for automated image analysis pipeline in ecology laboratories.

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Genomics in arctic fox conservation and ecology: development and utility of the custom fox Affymetrix 702k array

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The arctic fox is listed as endangered in Scandinavia, with a current population census of approximately 300 individuals divided into several isolated populations, many of which are subject to intense conservation management such as supplementary feeding and release of captive bred individuals. Harsh alpine conditions, stochastic prey availability and red fox competition is likely to impose strong selection pressures on the arctic fox. We present a genomic tool of 507,000 SNP markers for the detection of adaptive genetic variation in the arctic fox genome. The panel is based on 12 individuals originating from seven locations in Scandinavia, as well as one individual each from Canada, the peninsulas of Kola and Yamal, and a fur-farmed individual. These were re-sequenced at 11x coverage and aligned with the un-annotated arctic fox reference genome, revealing 24 million SNPs. The 507,000 arctic fox SNPs on the Affymetrix Axiom Fox 702k array were selected to be 1) in proximity to all functional genes according to the annotated dog genome and 2) to be evenly distributed along the arctic fox reference genome with a mean inter-marker distance of 4,700 base pairs. This design is expected to capture both functional and neutral genetic variation. We genotyped 700 arctic foxes on the panel and achieved a call rate of 92%. We expect that this data will elucidate the genetic architecture of important adaptive traits and aid the ongoing conservation programme in making informed management decisions to ensure the recovery of the arctic fox in Scandinavia.

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Diversity of the Major Histocompatibility Complex gene, DRB1, in Arctic Fox (*Vulpes lagopus*)

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Sub arctic tundra populations of arctic fox are under increasing threat of localized extinction due to a variety of climatic and anthropogenic factors. These pressures mean that captive breeding for release programmes are becoming essential components of long term recovery efforts for this species. As such it is important that stakeholders be provided with the information needed to limit the loss of genetic diversity essential for long-term fitness and survival. Genes of the Major Histocompatibility Complex (MHC) in particular have been identified as suitable targets for such genetic conservation in breeding programmes.

We have combined previously published partial arctic fox sequences with new complete sequence data derived from new primers for exon 2 of the class II DRB1 gene for 120 arctic foxes and 300 red foxes.

We have identified 20 DRB1 alleles to date, of which eight match the published sequences. However, we have three different alleles that match one published sequence, indicating that much variation remains undetected in the published populations. The number of alleles per population range from 5-17, with the highest number in the largest population tested (n=5-63).
Interestingly, one allele found in arctic foxes from Sweden, was also found in red foxes from several European countries. Another wide ranging arctic fox allele, was also found in Alaskan red foxes.
Preliminary data for DRA shows that the Arctic fox has one allele which is also found in the Kit fox. This allele is different from the single allele shared by a number of other canid species.

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Impact of personality: relevance of findings from swift, San Joaquin and island fox conservation to arctic fox

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The study of personality in non-human animals has broadened in discipline over recent years, with theoretical and applied advances in behavioural ecology and conservation. Integrating consideration of personality into conservation management may increase the likelihood of survival at the individual level, thus ultimately assisting with achieving population level goals. Findings from personality and conservation focused studies are discussed with particular emphasis on relevance to arctic fox (*Vulpes lagopus*) conservation threats. Post-release survival and movements of reintroduced captive-bred swift fox (*Vulpes velox*) were shown to relate to individual boldness levels, with high boldness being detrimental. Captive California Channel Island fox (*Urocyon littoralis catalinae*), released on Catalina Island with no predators, showed opposite patterns to swift fox, with increased boldness being positively associated with faster pairing of mates and higher reproduction. Boldness influenced survival, dispersal and reproduction of free-living San Joaquin kit fox (*Vulpes macrotis mutica*) in two habitats with differing selection pressures, with a trade-off effect between higher levels of boldness and survival or reproduction observed. Understanding how individual personality may impact conservation strategies for arctic fox, for example on release from captive breeding facilities, or in habitats with differing selection pressures may allow for strategies to be tailored at the habitat or even the individual level to facilitate success.

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Evaluation of invasive and non-invasive methods to monitor lemming abundance in the Canadian Arctic

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Lemmings are the primary prey of arctic foxes (*Vulpes lagopus*) in many areas and have a strong influence on their demography. Annual lemming abundance is a key parameter to monitor when studying arctic fox population dynamic and trophic interactions in arctic ecosystems. We evaluated the performance of various methods (snap-trapping, winter nests counts, burrow counts and incidental observations) to assess lemming abundance with the long-term data available from the Bylot Island monitoring program over a 9-year period. To do this, we correlated estimates obtained with these methods to animal density estimated with spatially explicit capture-recapture models based on live-trapping data, which was considered the most precise and least biased method. Methods using direct observations in the field, namely snap trapping (r = 0.90) and incidental observations (r = 0.92), yielded the highest correlations with live-trapping densities. Indices from winter nests and burrows were also correlated (r > 0.50) with live-trapping densities, but to a lesser degree. We also evaluated the impact of reduced sampling effort on the bias and precision of each abundance estimate. Based on this work, we developed two manuals to promote and facilitate the monitoring of lemming abundance across the Canadian Arctic. The first one describes in details and in simple terms several methods to sample lemming abundance in the field. The second one describes analytical methods to estimate lemming abundance using capture-recapture methods and winter nest density using distance sampling.

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Poster Session

Poster 1

The effect of management on effective population size in the Arctic fox (*Vulpes lagopus*) metapopulation in Scandinavia

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Estimates of effective population size (N_e) may provide insight to patterns of changes in allele frequencies and heterozygosity in a population. Furthermore, by estimating N_e, one can predict future changes in genetic diversity because N_e determines the rate of random genetic drift. N_e is usually smaller than the census population size, N_c, typically ranging from 0.25 – 0.75 in vertebrate species, most often below 0.5. In this study, two approaches were applied to estimate N_e in three arctic fox populations in Scandinavia from 2008 to 2015. The Scandinavian arctic fox has been protected for more than 80 years. Around year 2000, implementation of conservation actions were initiated as a part of the national action plans for the arctic fox, which have been intensified since 2007. Over the study period, there was an increase in N_c, closely linked to the implemented management actions, applied at different intensity in the three subpopulations. In general, my results showed that there was an increase in the N_e in all three subpopulations, and further an increase in the ratio of effective to census population size (N_e/N_c) from the implementation of management actions and throughout the study period. However, in 2015, the arctic fox subpopulations have still not reached a viable population size and hence continued actions are needed. Nevertheless, the observed increase in the N_e/N_c – ratio within each subpopulation and the metapopulation over the last decade, may suggest an improved chance for persistence of the Scandinavian arctic fox population in the future.

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Poster 2

Felles Fjellrev – a borderless management project to increase the Arctic fox population in Scandinavia

Felles Fjellrev core group

Project owners
County Administrative Board of Jämtland, Sweden
Norwegian Environment Agency, Norway

Felles Fjellrev is supported by EU and Interreg Sweden-Norway

Arctic fox in the EU

The Arctic fox is one of the EU's most threatened mammals. Hunted close to extinction a hundred years ago, there is now only one small breeding population left in the EU. This population is located on the border between Sweden and Norway. Thanks to successful conservation efforts, the situation is slowly starting to look brighter.

Concrete support measures and management-focused research.

Felles Fjellrev (2010-2014) had excellent results and Felles Fjellrev II (2016-2019) will further strengthen the Arctic fox's status. Continued support measures in the field are necessary to improve the Arctic fox's chances of survival. These should be supplemented by research relating to the future management of the species. In these areas, we work with the Norwegian Institute for Nature Research (NINA) and Stockholm University.

Communication, information and increased accessibility.

Communication with the public, by Felles Fjellrev website, Facebook, Instagram, printed information material and an animated short film, are important parts of the project. "Fjellrev I sekken" – a web-based interdisciplinary educational materials for schools, where children, through Arctic foxes, learn about mountain ecology and threatened species – has been produced and will be adapted for Norwegian and Swedish schools.

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Poster 3

Weather variability has no direct impact on adult survival in Arctic foxes

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Natural causes of mortality in carnivores are not well known, thereby causing a lack of understanding of their demography. Indeed, the majority of studies on the sources of carnivore mortality were done on populations facing anthropological threats, such as hunting or car collisions. Moreover, resource variation sometimes fails to explain survival patterns. Here, we evaluated the role of weather as a possible factor causing mortality in Arctic foxes. To do so, we used satellite collars to determine monthly survival of individuals during an 8-year study in the High Canadian Arctic. In a known-fate capture-recapture analysis, we tested local (temperature, wind speed and snow precipitation) and regional (Arctic Oscillation) weather variables at a monthly and seasonal time scale. Because food resources are critical to the life history of carnivores, we also tested the interactions of these variables with prey availability. We found no strong evidence showing that weather variables affected monthly survival of this carnivore even in interaction with prey abundance. Given that weather does not significantly impact mortality in Arctic foxes, it is unlikely that climate change has any direct effects on individual mortality in this species, at least in the center of its distribution range where we conducted this study. Despite the technical difficulties underlying the close monitoring of top predators, it remains essential to better understand carnivores' demography in order to understand and predict the impacts of global changes on ecosystems.

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Poster 4

An individual-based model of the population dynamics of the Arctic fox (*Vulpes lagopus semenovi*) on Mednyi Island (Commander Islands, North Pacific)

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A spatially explicit individual-based model was developed for the population dynamics of the endangered Arctic fox on Mednyi Island. The model is based on field data collected during 19 years. Annual marking of cubs allowed us to identify up to 80% of animals individually and to collect their life-history data. We determined mortality rates of males and females of all age classes, sex ratios for each age class, probabilities of breeding and litter sizes. In addition, we mapped social structures, dispersal distances, and patterns of selection of social partners and habitat patches. The model is spatially explicit, i.e., heterogeneity of habitat patches is defined in an explicit form. In simulations, such demographic parameters as population dynamics, population age structure, sex ratio in different age classes, and structure and size of families conformed to the empirical data.
The analysis of the model sensitivity to changes in mortality rates in different age classes showed that the sensitivity to increased mortality of cubs is much higher compared to adults of all age classes. Increasing the cub mortality rate to 95% over a period of one to five years, we simulated the effect of an otodectic mange epizootic, which was observed in the real population of Mednyi Arctic fox. The population recovery time after the end of the impact was significantly longer in the simulations compared to the field data. We suggest that in reality, with a low population size, the productivity of the population increases, and the mortality of cubs may decrease.

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Poster 5

Population dynamics of the Bering arctic fox (*Vulpes lagopus beringensis*)

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The arctic fox population on Bering Island is one of two ancient endemic arctic fox subspecies on Commander Islands. Although there was no population crash like in the case of arctic foxes on neighboring Medny Island, similar risks in both populations exist, and monitoring the Bering population is needed.
Currently such monitoring is performed in two ways: springtime counting of individuals and summertime counting of litters. Springtime counting has been conducted more or less regularly since 1995, but the most complete and representative data was collected in 2013-2016. The litters were counted in 2009, 2012-2014 and 2016. The litters monitoring throughout the island was performed in 2014.
There was no stable trend towards population decline or growth in the last few years. The total population is estimated at about 400-600 adults, with minor annual fluctuations. Total number of litters was estimated at about 90-100 in 2014, near the same number in 2009, 2013 and 2016, but only half of this in 2012, presumably due to weather conditions of that year. This is a typical coastal arctic fox population without drastic fluctuations because of abundant and stable food sources.
On the other hand, some facts speak in favor of a population decrease that could have taken place in the last 25 years. For instance, litter density in 1991 and 1992 was estimated twice higher than compared to our data. Therefore it is necessary to continue with annual monitoring of the population and of state of the environment.

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Poster 6

Selection of breeding dens in different habitat types by Arctic foxes in southern Yamal, Russia

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Choices made in the selection of breeding sites are likely to affect reproductive success, but are not always well understood. Better understanding of the factors that influence breeding site selection may therefore benefit conservation efforts of species under threat of environmental changes, such as Arctic foxes in much of the circumpolar North.
We investigated denning site selection of Arctic foxes in Southern Yamal Peninsula (Russia) by using an 11-year dataset on den occupancy, and den locations within a habitat map of the study area. This map includes five distinct vegetation types and water bodies. The availability of resources for foxes in each vegetation type was indirectly quantified using faeces counts (hare and ptarmigan) and small rodent trapping. In addition, small scale den characteristics such as slope, aspect and den size were analysed against den occupancy.
We expected that dens in closer proximity to willow thickets, dwarf birch shrubs, and water bodies were selected by arctic foxes during low phases of the small rodent cycle, as these habitats are thought to have higher densities of alternative prey species, such as ptarmigan, hare and waterfowl. During high phases of the small rodent cycle, active dens are expected to be found near wet habitats as well, which is the preferred habitat of *Microtus middendorffii*, one of the common voles species in the area. Furthermore, southerly slope exposure and den size are expected to be positively correlated with den occupancy.
Results will be presented at the conference.

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Poster 7

Developing a vulnerability index to climate change for arctic fox dens

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Vulnerability is commonly defined as the combination of exposure, sensitivity, and adaptive capacity of a system to one or more specified hazards (IPCC 2007). Knowing that climate change enhances the range and occurrence of many arctic geohazards affecting permafrost, we decided to conduct a climate change vulnerability assessment in our study area, Bylot Island (NU, Canada). Our species of interest is the arctic fox (*Vulpes lagopus*), which highly depends on a stable and perennial denning site for protection and breeding in the harsh arctic environment. Since arctic foxes are very mobile organisms that can cope with slow alterations of their dens by digging out new or collapsed holes, we only considered moderately-fast to fast permafrost degradation processes (specifically thermo-erosion, mass movements and thaw settlement) as having a potential impact on den vulnerability. We conducted our assessment using an approach called multi-criteria decision analysis (MCDA), which combines the information from several criteria to form a single index. The first step was to identify a set of indicators (criteria) as having the greatest impact on arctic fox dens through climate-related hazards, namely slope, erosion, ground ice content, and surficial deposit. The second step was to compare these criteria against each other to determine criteria weights. Finally, our four criteria were evaluated for each den (n = 102) with observations both on the field and from aerial photographs to produce an output map representing the distribution of den vulnerability in the study area.

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Poster 8

Contact between wildlife, domestic animals, and people in Arctic communities: implications for disease transmission

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In the Arctic, wildlife may enter communities in order to access resources, resulting in interactions between wildlife, domestic animals and humans that increase the risk of transmission for zoonotic diseases such as rabies. The objectives of this project are to characterize distribution of foxes in northern communities to assess the spatio-temporal risks for fox-dog contacts and to identify the factors influencing the distribution of foxes and dogs around communities. We set a network of trail cameras on a spatial grid surrounding Kuujjuaq (close to the treeline) and Inukjuak (>100km away from the treeline) to detect the presence of both carnivores. From March to August, we accumulated a total of 3,092 and 443 camera-nights (CN) in Kuujjuaq (2016-2017) and Inukjuak (2017), respectively. All foxes observed in Kuujjuaq were red foxes and 56% were Arctic foxes in Inukjuak. The mean coefficient of daily activity overlapping between dogs and foxes was 0.51(±0.22) while seasonal activity was highest at the end of April for foxes (0.025 obs/CN) and at the beginning of June for dogs (0.058 obs/CN). In both communities, foxes can be observed <1km from human settlements and 15% of camera station in Kuujjuaq had presence of dogs and foxes at the same station compare to 4% in Inukjuak. These results suggest that contacts between foxes and dogs may be higher at the end of winter, and contacts could occur very close to town, increasing disease risk for humans. This study provides the first documentation of fox activity and their interactions with dogs and humans in Arctic communities.

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Poster 9

Patterns of host genetic structure in relation to virus variation in fox rabies epizootics in northern Canada

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Although rabies is endemic in the Arctic, origins and spread of epizootics of this lethal zoonotic disease are little understood. We report the population genetic structure of coloured (*Vulpes vulpes*) and arctic foxes (*Vulpes lagopus*) across northern Canada, and compare it with virus variant distribution, to better understand the movements of vector and virus across the landscape. Analysis of mtDNA revealed some genetic structure in coloured foxes on a broad scale, but little genetic variation within Labrador, and no host genetic structure among arctic foxes. Microsatellite analysis of coloured foxes provided finer scale resolution of host genetic structure in eastern subarctic and was able to differentiate southeastern populations from each other and from western and northern locations. Viral genome sequencing identified a variety of sub-types of the arctic A3 lineage that has circulated across northern Canada since the late 1990s. In areas of fox host range overlap, both coloured and arctic foxes shared many of the same viral sub-types, while distinct sub-types did occur in areas of host allopatry. However from 2010 onwards only two viral sub-types circulated across northeastern Canada and only one of these was responsible for all rabies cases from Labrador over this period. This work provides baseline data on fox population structures and their correlation with virus distribution, information that will inform modeling studies for the prediction of future fox rabies outbreaks which will in turn aid the development of strategies for managing a disease affecting wildlife, domestic animal and public health in the Arctic.

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Poster 10

Linking large-scale movement strategies of arctic foxes and epidemiology of rabies: A spatially explicit individual-based approach

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Arctic fox rabies is an ongoing threat to human populations and domestic animals in northern polar areas, where arctic foxes (*Vulpes lagopus*) are the main reservoir hosts. Climate change is shifting the distributions of arctic species, and this may affect the risk of rabies transmission and spread. Our understanding of the effects of climate change on space-use patterns of arctic foxes and their consequences on the dynamics of rabies epidemiology remains limited, in part, due to the difficulty of obtaining ecological data from such a remote and expansive region. Simulation models help study ecological complexity of host-pathogen systems. In this perspective, we apply a spatially explicit individual-based model to assess the interplay between large-scale movement strategies of arctic foxes and epidemiology of rabies in the context of climate change. The model is parameterized using a combination of field data collected on Bylot Island and published empirical studies from other arctic regions. Here, we will provide an overview of different ecological and epidemiological processes of the model and will describe the general framework for integrating large-scale movement strategies of arctic foxes. Ultimately, our study will provide new insights into the mechanisms of rabies transmission and spread among arctic foxes, and will help to develop more cost-effective prevention strategies for rabies in the Arctic.

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Poster 11

Intestinal parasites of the arctic fox (*Vulpes lagopus beringensis*) on Bering Island

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There are rather few studies on the parasite fauna of endemic arctic fox (*V.l. beringensis*) on Bering Island. Due to possible influence of parasite load on Bering arctic fox mortality and subsequent population dynamics, analysis of the species composition and the prevalence of parasites in the population is needed.

Arctic fox feces were collected on the northern part of Bering Island in the summer of 2015 (3 samples) and the spring of 2017 (85 samples). The prevalence of helminth eggs was 71.6%, and 9 helminth species were found. Dominant species – cestodes *Diphillobothrium* sp. (prevalence 23.9%), *Taenia* sp. (*Echinococcus multilocularis*?) (19.3%) and nematode *Toxascaris leonina* (22.7%); subdominant spp. – nematodes *Ancylostoma caninum*, *Uncinaria stenocephala*, *Spirocerca arctica* (17%, 14.8% and 9.1% respectively); rare spp.– nematodes *Toxocara canis* (2.3%) and *Physaloptera sibirica* (1.1%). *Anisakis* sp. larvae were found at the incomplete helminthological autopsy of a single fox. More than one species were recorded in 27.3% of all the samples (more often - 2 species, less often - 3 species). *A. caninum*, *S. arctica*, *T. canis* and *P. sibirica* were found in *V.l. beringensis* for the first time.

The possible belonging of the taeniid type eggs to the *E. multilocularis* is based on the fact of the previously described high prevalence of this species in Bering arctic fox, with accidentally introduced northern red-backed vole *Myodes rutilus* as intermediate host.

Species predominated in the Bering arctic fox are specific for the Yakut arctic fox helminth faunal complex. This can be related to certain biotopic features.

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Poster 12

Competition between Arctic and red foxes at the expanding front of the red fox in the Canadian Arctic

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Arctic wildlife species possess a number of morphological, physiological, and behavioural adaptations to the harsh and variable Arctic climate, but are considered particularly vulnerable to ongoing environmental changes. The expansion of boreal species into the tundra can have severe consequences on endemic species. During the past century, the red fox *(Vulpes vulpes)* has expanded its distribution into alpine and arctic tundra. Red foxes usually exclude Arctic foxes *(Vulpes lagopus)* at the regional level, but several cases of local sympatry have been reported, corresponding to a relatively narrow overlap zone of their distribution ranges. There is a need to improve our capacity to predict the ecological consequences of northward changes in boreal species distributions. The Arctic tundra is an ideal arena to test the concept of how ecosystem productivity can limit the expansion of a generalist mesopredator, and promote the coexistence of two competing mesopredators. We will present preliminary results of a study based on data collected since 1993 on Bylot Island, Nunavut, Canada, at the northern limit of the expanding front of the red fox. The aims of this 15-year study were to: (i) estimate and compare the energetic requirements of sympatric arctic and red foxes in the Arctic tundra, at the northern limit of the red fox range; (ii) describe the ecological niches of both fox species during the breeding season; and (iii) assess how the presence of red foxes affects arctic foxes at the scale of the study site.

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Poster 13

Influence of the distribution of medium-sized prey species on the presence of red foxes in the south plain of Bylot Island, Nunavut, Canada

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In the south plain of Bylot Island, the Arctic fox is the dominant predator, but a few red foxes are established in the northern part of the study area. The goal of this study was to assess if medium-sized prey species (arctic hare *Lepus arcticus*, rock ptarmigan *Lagopus mutus* and sandhill crane *Grus Canadensis)*, which should provide a good energy source for red foxes in spring, influenced their presence in that particular part of our study area. We analyzed 200,000 pictures taken by 66 automatic infrared cameras placed on dens in 2013 (end of May-early July). We mapped both an activity index and an index of presence/absence around fox dens for these three medium-sized prey species. We focused on the critical period of late May, when energetic needs of reproductive foxes are high but migratory birds have not yet arrived. The results showed important arctic hare concentrations in areas displaying a sharp topography, but no marked increase in their activity near red fox dens. However, sandhill cranes were highly found in the red fox range. No significant result emerged for the rock ptarmigan, mainly because 2013 was a low density year for this species in the study area. These results suggested that the distribution of medium-sized prey species did not seem to explain the distribution of the red fox in our study area. The study should however be replicated across years to validate the results. Yet, our preliminary results open up an intriguing research question.

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Poster 14

Plovers with broader distribution breed away from Arctic fox's fangs

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The importance of biotic interactions for species distribution and range limits is still highly debated and their effects at broad spatial scale are often overwhelmed by abiotic factors like climate or difficult to assess because of the complexity of inter-specific interactions. In the Arctic tundra, characterized by relatively few vertebrate species, the Arctic Fox (*Vulpes lagopus*) is the key predator of birds' nests and has a wide circumpolar distribution. We hypothesized that arctic-nesting birds which can persist over most of the Arctic Fox distribution range are less vulnerable to predation because they use safer nesting habitat (partial refuge against predation) compared to those having more restricted breeding distribution. During a four years study, we tested this hypothesis in the Canadian High-Arctic (Bylot Island, Nunavut) by quantifying nest survival rate of two shorebird species with contrasting distribution range, and by conducting field experiments with artificial nests to quantify predation risk in the main nesting habitat used by each species. As predicted, we found that the widely distributed Ringed Plover (*Charadrius hiaticula*) nesting along stony riverbanks showed much higher nest survival rate (with 87% hatching probability) than the Golden Plover (Pluvialis sp) nesting in mesic tundra (with 28% hatching probability). Using artificial nests, we confirmed that such differences in nest survival were at least partly driven by habitat type per se with 71% higher survival in riverbanks than in mesic tundra. Overall, our study provides evidence that some species with wider distribution are less vulnerable to predation because they use safer nesting habitat. This supports the idea that predation can be an important biotic factor affecting bird species distribution range.

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Poster 15

The genetic basis of litter size in Scandinavian arctic fox (*Vulpes lagopus*)

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Conserving genetic diversity is an important part of biodiversity, especially in small populations where genes can be lost to genetic drift. Application of genetic management of threatened species in the wild is however still in its early stages.
The arctic fox captive breeding programme has been an important contributor to the gene pool of the arctic fox population at Snøhetta, through release of captive born cubs (n= 102). The population is however founded by only 16 individuals originating from different subpopulations in Scandinavia. Genetic drift is expected to lead to a loss of genetic diversity, and adaptive genetic variation may therefore also be lost by pure chance.
The litter size in arctic foxes is highly dependent on fluctuations in the environment, with many cubs born in years with high rodent densities. If genes contribute to some of this variation, and any alleles that make Scandinavian arctic foxes enable to fully exploit years with high prey density are lost, this may reduce the ability of the arctic fox population to increase in size to be viable in the long term. Examining the genetic basis for, and trying to identify genes that contribute to litter size may thus be important for the future conservation and management of this species in Scandinavia.
This planned MSc will focus on the genetic basis of variation in litter size in arctic foxes. I will examine the genetic architecture by: 1. Measure additive variance and heritability, 2. Chromosome partitioning and 3. Genome wide association study.

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Poster 16

Fitness correlates of Arctic fox fur coloration in Norway

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Arctic foxes exist in two distinct colour morphs, white and blue, and the proportion of the two morphs varies geographically. Since 2007, both white and blue Arctic foxes have been released in Norway through the captive-breeding and reintroduction programme, as part of the national action plan to support threatened Arctic fox populations. The main objective of this study is to assess the contribution of the two colour morphs to the recovery of the Arctic fox population of Dovrefjell, central Norway. I will describe the current distribution of the two colour morphs and compare it to the proportion of released foxes in this mountain area where the Arctic fox was practically absent until (2007). I will compare the fitness of the two colour morphs according to the average snow cover, in looking at both survival and reproductive success. This will allow us to discuss the influence of released foxes on the proportion of white and blue morphs and estimate their contribute to the wild population. The results of this study may offer unique insights into the Arctic fox's ability to adapt to changes in snow cover as the climate changes.

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Poster 17

The underlying basis of seasonal color molts in Arctic fox

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Arctic foxes, as well as over 20 other species of birds and mammals, undergo seasonal coat color molts to match snowy backgrounds. Not all individuals, however, become white in the winter and color polymorphism is widespread across species. The arctic fox has two major color morphs; the invariant blue- and the color changing white morph. We reviewed the functional, physiological and molecular basis of seasonal color molting and polymorphism in arctic foxes and pinpointed analogous underlying mechanisms as in other color molting species. Next, we described the phenology of seasonal molts in both white and blue foxes in Sweden and compared our findings to previous empirical studies on color molting mammals. Based on two years of nearly continuous field monitoring, we showed similar progression and effects of various factors on the molt phenology in the two morphs as in other molting species. Lastly, we identified key areas regarding the color molts and polymorphism that deserve further attention, especially for understanding the impacts of climate change.

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Poster 18

Dietary exposure to persistent organic pollutants increase asymmetry and affect periodontal disease in farmed Arctic foxes (*Vulpes lagopus*)

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We examined mandibles from brother pairs of farmed arctic foxes (*Vulpes lagopus*). During ontogeny, one brother was exposed to dietary POP's (persistent organic pollutants) via naturally contaminated minke whale (*Balaenoptere acutorostarta*) blubber (n=10), while the other was fed a diet of pig (*Sus scrofa*) fat as a control (n=10). The ∑POPs concentration was 802 ng/g w.w. in the whale blubber, compared to 24 ng/g w.w. in the control diet.

Qualitatively, we observed a high incidence of periodontal disease in both groups with a greater severity of sub-canine alveolar bone deterioration in the POP-exposed group. There was also a high incidence of abnormal, but likely non-pathogenic, non-metric variants in the exposed group; foxes missing caudal mental foramina, and elongate bone spurs on the condyloid and coronoid processes were observed. The sample size was too small to assess differences between the two groups using traditional methods. To quantify these changes, and more subtle shape disruptions, we conducted a two-dimensional geometric morphometric (GM) analysis of shape and asymmetry between the two groups.

The GM analysis found that asymmetry between the left and right halves (Two-Way ANOVA, $F=8.93$, $p=0.095$) in the exposed group was greater than the controls (Two-Way ANOVA, $F=4.39$, $p=0.3267$) though not statistically significant. The overall mandibular shape between groups is significantly different when a discriminant function analysis is performed ($T^2=58.52$, $p=0.04$, 1000 permutations).

These findings provide a basis for further GM studies of natural populations that experience exposure to environmental contaminants during development as an alternative to traditional morphometric methods.

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Poster 19

Measuring hair cortisol as a tool for improving conservation actions? Insights from Arctic fox research in Norway

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Hair cortisol in mammals and feather corticosterone in birds are increasingly used a biomarkers of long-term stress, although the relationship between glucocorticoids, environmental conditions, and the biology or health of individual animals is often unclear. The aim of this study was to evaluate the utility of hair cortisol as an integrated biomarker of long-term stress and to assess its potential to serve as a practical conservation tool of wildlife species, using the management of the Arctic fox *(Vulpes lagopus)* in Norway as a case study. To address this, we measured hair cortisol in 56 captive-bred and 116 wild-born juvenile Arctic foxes and first assessed whether individual state and environmental conditions could predict hair cortisol levels. Environmental parameters reflected food availability, intra- and inter-specific competition, human presence around den sites, and weather conditions. Second, we tested if hair cortisol levels could predict future survival and breeding success of Arctic foxes. Hair cortisol levels were on average 6.03 ± 2.81 pg/mg hair (mean ± SD; range: 1.61 – 20.4). In captivity, hair cortisol levels were correlated to fox age and average air temperatures during the past 30 days before hair sampling. For wild-born foxes, we did not identify any clear relationship between hair cortisol levels and available individual state and environmental parameters. Finally, for wild-born, but not for captive-bred foxes, hair cortisol significantly predicted survival after the first winter. We will discuss how measuring hair cortisol levels could be used as a tool to support and adapt management decisions in the future.

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Poster 20

Methods of assessing personality in the arctic fox (*Vulpes lagopus*) in a captive breeding programme

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Releasing captive-bred individuals is one of crucial conservation actions for an endangered population. It has been suggested that personality of an animal could be a release criterion affecting its fitness and dispersal, and releases of a mixture of personalities would provide a greater adaptability in a population. The arctic fox (*Vulpes lagopus*) is critically endangered in Norway and has been captive-bred and released across Norway since 2005 from Sæterfjellet captive breeding station, Norway located in their natural habitat. To assess personality of arctic foxes, here we present three different ways of measuring individual variation in personality along with behavioural observation. For behavioural observation (BO), we observed behaviours of juvenile arctic foxes in the station before release from 2012 to 2016 and calculated behavioural budgets for each individual. Then, we tested personality of juvenile and adult foxes by novel object test (NO), movement rating (MR), and human test (HT) from 2014/15 to 2016 to measure exploration, activity, and boldness scores for all individuals. We found no difference between sexes in all personality scores but found litters are significantly different in exploration levels (NO; $F_{8,37}$ = 2.73, p = 0.018, MR; $F_{6,26}$ =2.546 p = 0.04492). The results provide a basic for measuring personality traits of individuals in captivity and further studies linking this variation with post-release survival and dispersal would be needed for a better conservation plan.

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Poster 21

Implementing measures of individual behavioural variation in the Arctic ecosystem: can we assess personality in arctic foxes?

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Intraspecific variation is predominant in natural populations, and the consideration of behavioural diversity at the individual scale has recently shed light on many ecological processes. The integration of animal personality to community ecology however remains relatively scarce, although consistent individual differences in behaviour could be important in shaping predator-prey interactions among trophic dynamics. With the aim to initiate discussion on the integration of such questions within studies at the ecosystem scale, we present preliminary results from behavioural tests and measures implemented during captures of arctic foxes (*Vulpes lagopus*) monitored on Bylot island, Nunavut, Canada. We first found a positive correlation between the two aggressiveness scores independently measured during fox captures and manipulations. Additionally, the more aggressive juveniles tended to show an aggressive reaction towards an object introduced in the cage, and adults' aggressiveness was positively associated to risk-taking tendency displayed by individuals upon release. Individual fox reactions could thus reflect a behavioural syndrome, although it would be necessary to obtain repeated measures of each test to further investigate personality effects. We finally present how these promising exploratory measures could be coupled to behaviours recorded during natural observations and through technological devices, while hoping that they could stimulate a potential implementation in other circumpolar surveys.

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Poster 22

Picking the right cache: hoarding-site selection for egg predators in the Arctic

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Food caching is often considered as an adaptive behaviour to extend the period of food resources availability. Finding the right spot to cache resources for storage and retrieval is paramount. Yet how cache habitat selection occurs is poorly documented in canids. The Arctic fox (*Vulpes lagopus*) is a top-predator living in the tundra. In such habitat, foxes face large fluctuations in prey availability, which they overcome by caching food. During the short Arctic summer, eggs laid by breeding birds represent a pulse of resources, used by foxes for both immediate consumption and caching. Our objective was to investigate caching site selection by Arctic foxes. We recorded the main features of tundra habitats at 48 caches and control sites within the breeding colony of Greater Snow goose (*Chen caerulescens*).

Food caches were mainly located in sites with shorter vegetation and a larger moss cover compared to control sites. Cache sites were also characterized by higher hummocks (i.e. small mounds typical of the tundra landscape) and shallower permafrost than control sites. Our results suggest that foxes use large- and small-scale visual cues in the vegetation size, shape of ground and landscape features to select cache sites. Such characteristics of cache sites may also facilitate the creation and camouflage of the cache, as well as improve conservation of the cached eggs. We provide baseline information for food cache habitat selection in a cold environment by canids. Our study illustrates predator adaptation to extreme habitats characterized by strong variations in resource availability.

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Poster 23

Red and Arctic fox sea ice use and spatial interactions at the edge of Arctic

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Rapid changes are occurring in the northern ecosystems in response to global warming and anthropogenic disturbance. As taiga species encroach onto the tundra, competition with tundra dwellers may occur. In northern Manitoba, where tundra, taiga and marine ecosystems merge, red foxes recently increased their use of tundra dens along the coast of Hudson Bay that were historically occupied by Arctic foxes, but little is known about their habitat use or possible impact on sympatric Arctic foxes. In May 2017 we deployed satellite collars (Telonics Inc., USA) on 6 foxes (one female and two males per species) to compare the use of the sea ice between red and arctic foxes, and understand interspecific interactions. We targeted occupied dens in an area where both species used adjacent dens and caught individuals from both species on the same dens. Sea ice was used by both species, but less by red foxes. Home range overlap between species was high (up to 52% overlap). Despite the high level of ecological similarity between the two species, red and Arctic foxes may cohabitate in our study area. However, continued declines of fox prey and loss of sea ice could induce competition between the two species, which could become detrimental to Arctic foxes.

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Poster 24

Long-distance movements of the first Siberian Arctic Fox equipped with satellite collar

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On March, 28, 2017 we equipped the first arctic fox with a satellite collar (Argos PTT) at the Erkuta long-term monitoring site (68,2 N; 68,9 E), southern Yamal, Russia. The arctic fox was trapped in a cage, and the collar was programmed with a duty cycle consisting of 6 h on and 42 h off. After release, the fox stayed in close vicinity from where it was trapped for 12 days. Then it performed several longer trips. It moved west over the Baidaratskaya Bay for a trip of ca 280 km, returned to the vicinity of the capture location and later moved east and north, over the Obskaya Bay to Gydan Peninsula. Overall the probably non-breeding arctic fox travelled extensively both over land and sea ice covering at least 1000 km (700 km in a period of 30 days), before the signals stopped on 25 of July.

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