6th International Conference in

ARCTIC FOX BIOLOGY

2022 | Longyearbyen | SVALBARD

PROGRAM & ABSTRACTS

26-29 August 2022
#arcticfoxconference

Fuglei E, Kibsgaard A, Nater C. Conference Secretariat, 2022
6th International conference in Arctic Fox Biology
26–29 August 2022, Longyearbyen, Svalbard, Norway

Program, abstracts and lists of participants
#arcticfoxconference

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Conference Secretariat

Chloe Nater, NINA

Anne Kibsgaard and Eva Fuglei, NPI

Welcome word

We are pleased to welcome you – in person or virtually – to high–Arctic Svalbard, Norway, for the 6th International conference in Arctic Fox Biology.

This conference has been and continues to be the most important meeting point for arctic fox researchers, conservation managers, policy makers, tour operators, students and any other people interested in arctic foxes, their habitats, and the ecosystems they are part of.

After being hosted by the circumpolar network of arctic fox biologists in Sweden (1991 and 2009), UK (2001), Iceland (2013) and Canada (2017), the conference's sixth iteration was scheduled to take place in Longyearbyen, Svalbard, for August 2020. Two years, two postponements, and one pandemic later, we are finally able to welcome you all to the conference – now in a new hybrid format – at the Svalbard Research Park, University Centre in Svalbard (UNIS)/Norwegian Polar Institute (NPI) in Longyearbyen.

Climate warming is rapidly increasing specifically in the Arctic and Svalbard is one of the locations in the Arctic where the impacts of climate change on ecosystems are fastest and most profound. The arctic fox, deemed "critically endangered" across parts of its distributional range, has been given a flagship status by the IUCN that exemplifies the vulnerability of arctic species and ecosystems to different aspects of climate change ranging from warming temperatures over food web alterations to zoonic diseases.

To emphasize and engage with the different ways in which climate change, but also increasing tourism, affect arctic foxes and their interaction with humans we kick off the conference with a workshop and panel discussion on the first day (26th August). The second and third conference days (27th & 28th August) are dedicated to presentations held by arctic fox researchers and stakeholders, and "Roundtable discussions" on emerging challenges for arctic foxes and arctic fox research. On the final day (29th August) conference participants can join a field trip with the hybrid–electric catamaran MS BARD, which will take us closer to nature, glaciers and wilderness in the Isfjorden area.

Whether you are joining us in person in Longyearbyen, or whether you are following the conference via our live–stream and Slack from the comfort of your own home or office: we hope that you will enjoy yourself and have a fantastic time.

Welcome to Svalbard!

Eva Fuglei, Anne Kibsgaard and Chloe Nater
The Conference Secretariat

Contents

1 Program

Friday August 26, 2022. MØYSALEN, Svalbard Research Park, UNIS

08:00–08:45	**Registration at the reception, poster set up**
09:00–09:15	Welcome by the committee (workshop goals, content and structure)
09:15–10:40	Workshop – ISSUES OF TOURISM AND ARCTIC WILDLIFE
10:40–11:00	**Coffee break**
11:00–12:00	Workshop – ISSUES OF TOURISM AND ARCTIC WILDLIFE
12:00–13:00	**Lunch (UNIS cafeteria)**
13:00–14:00	Workshop – ISSUES OF TOURISM AND ARCTIC WILDLIFE
14:00–15:00	**Panel discussion – ISSUES OF TOURISM AND ARCTIC WILDLIFE**
15:00–15:30	**Coffee break**
15:30–16:00	Discussion session, spreading of diseases in Arctic wildlife
16:00–16:30	Continue poster set up and registration
18:45	**Bus to "Icebreaker" and dinner at Camp Barentz in Adventdalen**
23:00	**Bus back to Longyearbyen and hotels**

Saturday August 27, 2022. MØYSALEN, Svalbard Research Park, UNIS

07:30–08:55	**Continue registration and poster set-up Reception UNIS**
09:00–09:30	Welcome word
Session I – Population status and monitoring Session. Chair: Chloe Nater	
09:30–11:00	Research talks Session I
11:00–11:30	**Coffee break**
Session II – Ecosystem approaches. Chair: Arild Landa	
11:30–12:15	Research talks Session II
12:15–13:15	**Lunch UNIS cafeteria**
Session III – Predation and competition. Chair: Dorothee Ehrich	
13:15–14:15	Research talks Session III (1/2)
14:15–14:45	**Coffee break**
14:45–15:45	Research talks Session III (2/2)
15:45–16:05	**Coffee break**
16:05–16:35	**Poster pitch**
16:45–17:45	**On-site Poster session (UNIS cafeteria)**
19:00–22:00	**Dinner UNIS Cafeteria**

Sunday August 28, 2022. MØYSALEN, Svalbard Research Park, UNIS

08:30–08:45 Information of the day

Session IV – Movement and spatial ecology. Chair: TBA

08:45–10:00 Research talks Session IV

10:00–10:30 Coffee break

Session V – Physiology and genetics. Chair: Øystein Flagstad

10:30–12:00 Research talks (Session V)

12:00–13:00 Lunch (UNIS cafeteria)

Session VI – Management and conservation. Chair: Rolf Anker Ims

13:00–14:15 Research talks Session VI

14:15–14:45 Coffee break

Session VII – Life-history and Demography. Chair: Eva Fuglei

14:45–15:30 Research talks (Session VII)

15:30–15:50 Coffee break

Session VIII – Diseases, parasites and pollution. Chair: TBA

15:50–16:50 Research talks Session VIII

16:50–17:15 Concluding remarks and practical info for dinner & field trip

17:20–18:00 Poster removal UNIS Cafeteria

19:00–19:10 Bus from Longyearbyen and hotels to Gruve 3

19:10–23:00 Arctic fox banquet dinner at Gruve 3, Bus back to Longyearbyen and hotels

Monday August 29, 2022. Field trip

Field trip by boat (including lunch) in Isfjorden for the conference participants.

08:00–08:15 Bus from hotels to Longyearbyen harbor

08:40–15:00 Field trip with the hybrid boat MS Bard in Isfjorden, including lunch on the boat

15:15–15:20 Bus from Longyearbyen harbor to hotels

18:00 Dinner at the STATIONEN restaurant

2 Abstracts oral presentations

2.1 Session I – Population status and monitoring Chair: Chloe Nater

Svalbard and the Arctic fox – an uncertain future?

Eva FUGLEI

Norwegian Polar Institute

The arctic fox is endemic to the Arctic tundra and an apex predator and scavenger with no natural enemies or competitors in the high Arctic Svalbard ecosystem. They are one of three terrestrial mammal species that live the whole year in Svalbard, and they are found almost all over the archipelago. They are harvested annually, but on Bjørnøya, the southerly island of Svalbard, they are protected.

Svalbard lacks cyclically fluctuating arctic small rodents (like lemmings) so the population is much more stable compared to most other tundra ecosystems. The arctic fox is abundant and functionally important because it affects prey species on land, through ground nesting birds like ptarmigan, geese and reindeer carcasses, and marine resources such as seabirds, seal cubs and seal carcasses.

Arctic foxes are reservoir for dangerous zoonoses. Rabies in Svalbard has an irregular outbreak dynamic and is probably not endemic. The prevalence of Echinococcus multilocularis is much dependent on the distribution of the introduced sibling vole (Microtus levis), which is an obligate intermediate host for this parasite.

Long term monitoring of breeding den occupancy has been conducted in two areas. Rapid climate change impacts on the population dynamics of the arctic fox through multiple drivers, such as access to reindeer carcasses, marine subsidies and zoonoses. The future fate of Svalbard's arctic fox population will depend on how climate change affects their most important prey – reindeer, geese and seabirds, as well as other marine food sources such as seals, which are dependent on the distribution of the sea ice, in addition to zoonoses. Fur lice were discovered for the first time in the arctic fox population in Svalbard in 2019, and the prevalence has increased dramatically since. It is uncertain how this situation will develop and how it will impact the arctic fox population in the future.

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The Arctic fox in Hornstrandir: a case study of an apex predator in an exclusive ecosystem facing new stressors

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The Arctic fox is the only native terrestrial mammal in Iceland and serves as a top–predator in a bottom up ecosystem with a twist of marine and inland input. As all native wildlife, the Arctic fox is supposed to have a favorable conservation status in Iceland, by law. However, the Arctic fox is believed to be harmful to live–stock and an intensive bounty hunting takes place in all regions of Iceland. The most important sanctuary of the Arctic fox in Iceland is Hornstrandir Nature Reserve, a 580 km2 remote peninsula in Northwest Iceland (66N;23W) where the fox has been protected since 1995. Monitoring the Arctic fox as a top predator, sheds a light on the health of the ecosystem and changes in other parts of the food web. Long term monitoring of den occupancy has been taking place since 1998 and hunting statistics from the area is available since 1958–1994. The reserve hosts a relatively stable population of 40–50 breeding pairs of Arctic foxes and five internationally important seabird colonies. Hornstrandir is popular amongst visitors and known for the magnificent landscape, huge bird cliffs and the Arctic fox. As the foxes of Hornstrandir have gained worldwide attention, their importance in tourism is increasing. Tourist and fox behavior on Cliff Hornbjarg has been monitored since 2008, with a focus on denning attention during the lactation period. In the study period of 1998–2020 Arctic fox density changed, number of litters in the bird cliff has dropped, and cub mortality has increased. The potential causes seem related to 1) declining seabird populations, 2) unknown hazards during the gestation period and 3) high tourist disturbance. The Arctic fox of the Hornstrandir seems to be facing new stressors and hopefully the adaptability of the species will make them overcome these difficulties as many others in the past history of the Arctic fox in Iceland.

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“The Arctic Fox” project in Sabetta (Yamal Peninsula, Russia)

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Arctic fox is the main predator in most terrestrial arctic ecosystems. Their inter–annual dynamics depends on the peaks of rodents, and in particular lemmings. However, Arctic fox uses all available food resources: alternative prey (e.g. birds and their eggs), carrion and humans food subsidies. Since 2014, we have been monitoring the Arctic fox population on 170 km2 in the high Arctic of Yamal Peninsula. Territory characterized by relatively high density of domestic reindeer herds and situated near the large liquefied natural gas factory (Sabetta, Yamal LNG project).

We aim to understand drivers of this Arctic fox population dynamic in the specific socio–ecological context of Sabetta, also addressing emerging management needs. The potential drivers in this system include the inter–annual dynamic of main prey (small rodents – voles and lemmings), Arctic foxes’ movements in different seasons and years, end of fur hunting era in 1990s, human food subsidies, marine subsidies, appearance of reindeer carcasses as a result of catastrophic weather events (rain–on–snow, icing) and the attacks of Arctic fox on reindeer calves. Every year we visited 36 dens, in 21 of which breeding was detected. From 2 to 15 dens were active each year (1.5 – 9.6/100 km²). The mean number of pups was 5.8 (1–15; SD = 2.6). We monitored density of small rodents and herbivores, the predation pressure on tundra nesting birds, recorded incidental observations of predators, surveyed fox movements using GPS–collars and begun socio–anthropological studies interviewing reindeer herders.

The proportion of breeding dens depending on the rodents’ density and availability of domestic reindeer carcasses. We didn’t find significant relation between the proportion of Active fox dens where reproduction was detected and the number of shift workers in the Sabetta area in particular year.

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

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The arctic fox on Bering Island is one of two ancient subspecies endemic to Commander Islands. This population has been isolated for almost 60 thousand years without natural enemies and mainly depends on marine sources. Despite the fact that there were no reports of population crashes, such as for the neighboring Medny Island, there are similar risks in both populations, and monitoring of the Bering population is necessary. Currently, such monitoring is carried out in two ways: counting individuals in the spring and counting litters in the summer. Spring counting has been carried out more or less regularly since 1995, but the most complete data was collected in 2013–2016, 2018–2019 and 2021. The litters were partially counted in 2009, 2012–2014, 2016, 2018–2019 and 2021. The Island–wide survey was conducted in 2014 with monitoring of reproductive efforts.

In the past few years, there was not any trend towards a decline or growth in the population and the total number is estimated at 300–600 adults, with small annual fluctuations. The total number of litters was estimated at 90–100 in 2014, about the same number in other years, also with minor annual fluctuations. Density of dens and frequency of den occupation by foxes depended mainly on local food sources distribution.

This is a typical coastal arctic fox population without drastic fluctuations due to abundant and stable food sources. On the other hand, some facts speak in favor of a population decline that could have taken place over the last 25 years. For instance, density of active dens in 1991–1992 was estimated to be twice higher compared to our data. In addition, the number of foxes harvested at the end of the 20th century is comparable to the entire modern population. Therefore, it is necessary to continue annual ecosystem–based monitoring on Bering Island.

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Population status of arctic foxes in Sweden

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The Swedish Environmental Protection Agency and the Norwegian Environment Agency have developed a common methodology and standardized guidelines for the monitoring of arctic foxes in Scandinavia. The methodology was developed in 2016 and implemented in both Norway and Sweden as of 2018. Monitoring have been carried out in previous years but has then only partly been based on the same methods and protocols. In order to estimate the population size and make an assessment of any trends and changes in the Scandinavian arctic fox, the foxes need to be surveyed annually. The monitoring takes place during winter and summer. In Sweden, a national monitoring program for arctic fox was established in 2018. Before 2018 the monitoring had a varying and somewhat uncertain funding through action plans, projects, and research. Both the planning and practical work have been carried out by Stockholm University (SU) in collaboration with the county administrative boards in Jämtland, Västerbotten and Norrbotten. The county administrative boards have to a large extent been responsible for the winter monitoring, while SU has carried out and been responsible for most of the summer ditto. Since 2018, the overall national monitoring of arctic foxes in Sweden is funded by the Swedish Environmental Protection Agency, but a large part of the underlying summer field work is still financed from elsewhere. In 2021, 64 arctic fox reproductions were documented in Sweden. The minimum number of adult foxes in Sweden is estimated to 128 individuals. A summary of previous years' monitoring results shows a significant growth of the arctic fox population in Sweden over the past 10–15 years even if there has been a change in recent year's lemming cycle. In time for the presentation at the 6th International Conference in Arctic Fox Biology we hope to have the first preliminary monitoring results from 2022.

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Arctic fox in rapidly changing low–arctic Erkuta (Yamal, Russia)

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Aleksandr VOLKOVITSKII[1],

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During more than 20–years of research in the tundra monitoring site "Erkuta" on Yamal peninsula (Russia) we have documented changes in biodiversity and terrestrial ecosystem structure. As a key predator endemic to tundra ecosystems, the arctic fox both reacts to and mediates changes in the food web. Since 2007, we monitor arctic foxes both in summer (den occupancy, litter size) and in late winter (automatic cameras at bait stations). In our study area, lemmings have been rare during a period of 15 years. In the absence of lemming peaks, low amplitude fluctuations of voles were driving the breeding activity of the arctic fox together with the availability of reindeer carcasses after winters of catastrophical mortality of domestic reindeer caused by rain–on–snow events. In 2020, however, the lemming population reached peak densities for the first time since 1999. At the same time, vole abundance was high, and the water vole (Arvicola terrestris) appeared in the study area. As expected, many arctic foxes were breeding both in the pre–peak year and in the peak year. Our monitoring aims at understanding how this population at the southern margin of the tundra biome will face multiple drivers of change. In addition to climate driven ecosystem changes, human activity is increasing in the area, both intensive reindeer herding, the traditional activity of indigenous Nenets herders, and recently in the frame of new gaz exploration. Red foxes are present, but they are not numerous, and arctic fox is the dominant fox species. Here we address trends in arctic fox breeding activity over the study period, as well as a possible trend in arctic fox presence in later winter. Overall, the data indicate that the population is stable over this, still rather short, time frame.

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2.2 Session II – Ecosystem approaches
Chair: Arild Landa

A cosmic view of tundra gardens: quantifying Arctic fox ecosystem engineering effects on plant productivity using satellite imagery

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Advancements in remote sensing technology have provided us with unique perspectives on how animals interact with their environments across large spatial scales. Until recently, there have been considerable trade–offs between the spatial resolution and temporal frequency of low–cost remotely–sensed data. The recent launch of the Sentinel–2 satellite provided a major advancement in satellite imagery, capable of acquiring images every 8 days at a 9–fold greater resolution (10 m) than previous comparable satellites. Using open access software (Google Earth Engine), we demonstrate the efficacy of using freely available Sentinel–2 imagery to quantify the effects of Arctic fox (*Vulpes lagopus*) ecosystem engineering on the phenology and productivity of vegetation around fox dens. We compared normalized difference vegetation index (NDVI) values, a common remotely–sensed index of plant productivity, from 84 Arctic fox den sites with (i) random sites, and (ii) paired control sites predicted by a fox den habitat selection analysis along the western Hudson Bay coastline in northeastern Manitoba, Canada. Using imagery from 2018–2021, we assessed plant phenology patterns by calculating NDVI values across 8 time periods during each growing season, while maximum plant productivity estimates were obtained by creating a time series composite of maximum NDVI values throughout the entire growing season. Consistent with previous work from the area, plant productivity was significantly greater at Arctic fox dens than other areas on the tundra. However, there were no substantial differences in plant phenology patterns between dens and the random/control sites. Our study provides a 'proof of concept' analysis on the efficacy of using publicly available software and high–resolution remotely–sensed data to evaluate the landscape–scale ecological effects of animal behavior.

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Modeling the seasonal Arctic trophic network and the centrality of the Arctic fox

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The Arctic is transforming at a fast pace with unprecedented climate change impacts. These novel conditions can drastically alter the species compositions and interactions in this biome with new species arriving and possible extinctions. Modeling seasonal trophic interactions in the Arctic is an essential tool toward predicting how large–scale food web structures will be affected. Here we explore the centrality of the Arctic fox in the Arctic trophic network at a circumpolar scale. To this end, we developed a metaweb, a model of all the predicted interactions among arctic species. This metaweb is built around the allometric scaling relationship between predators and their prey, which can be a major determinant of ecosystem functioning. To do so, we compiled the diet of terrestrial Arctic predators based on published literature and established a presence–absence matrix of the Arctic species at the circumpolar scale. We then mapped the structure of Arctic ecological networks in space. This allowed us to identify areas with the greatest complexity of interactions and those most sensitive to extinctions. Because of the logistic and access constraint, it is hard to get information on the trophic interactions during the winter period in the Arctic. For the first time, however, we predicted the Arctic terrestrial trophic network in winter at a large–scale, filling an important knowledge gap. We identified how the place of the Arctic fox changed across seasons with various scenarios of prey extinctions/decline (e.g. lemmings) or competitors arrivals (e.g. red foxes). This circumpolar study is quantifying the potential shifts in trophic interactions across a fast–changing Arctic. The results of our analysis will provide large–scale measures of species composition changes that can impact ecosystems and help predict the cascading effects.

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ECOFUNC – Understanding ecosystem functionality, expansion and retreat of species in the Fennoscandian alpine tundra under multiple drivers of change

Nina E. EIDE, Annika HOFGAARD, Øystein FLAGSTAD, Arild LANDA, Stefan BLUMENTRATH, Lars RØD–ERIKSEN og Jørn Olav LØKKEN

Norwegian Institute of Nature Research

The Fennoscandian mountain range is naturally fragmented, consisting of thousands of large and small islands of alpine tundra areas embedded in forested landscapes. The fragmentation is expected to be magnified, driven by global warming and land use change. Upward range shifts of the forest is associated with the invasion of boreal species, including a wide range of plant species and mammals.

The tree- and forest line is moving upward. Experimental altering of temperature and herbivory in alpine vegetation show that land use change is the prominent driver of both birch growth and plant community composition compared to climate warming. Tree lines show a larger degree of stability if the grazing pressure persist. Red foxes are expanding. We find a higher density of generalist predators close to infrastructure and human activity, likely linked to subsidies and surplus food/waist along the roads. Attracting boreal species into more marginal alpine areas could have cascading negative effects on native, alpine species, through increased competition within the predator guild (e.g. increased competition between the invading red fox and native arctic fox) or increased predation on e.g. ground nesting birds. However, occurrence of larger carnivores appears to modify the relationship between the two fox species; red foxes having less negative impact on arctic foxes where wolverines occur. We use advanced genomics to explore how red foxes move around in the large landscape, to identify drivers of their expansion, and explore risk of spreading diseases and parasites, which could have negative impact on native species and humans.

Where do functional alpine tundra landscapes persist, being large enough for long time survival of native mountain species? Where are areas important for connectivity maintaining; landscape functionality. Scenario tools could optimizing conservation programs, restoration of landscapes, targeting management actions, e.g. restoring the Fennoscandian arctic fox population.

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2.3 Session III – Predation and competition
Chair: Dorothee Ehrich

Living on the edge: spatial ecology of sympatric red and Arctic foxes

Chloé WARRET RODRIGUES, James D. ROTH

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University of Manitoba, Canada

Climate warming and increasing anthropogenic pressure are promoting the expansion of boreal–forest species onto the tundra. We studied spatial ecology of sympatric red and Arctic foxes, using satellite telemetry in northern Manitoba, Canada, where treeline transitions to coastal tundra. Such ecotones are characterized by the convergence of populations native to each transitioning habitat and often offer suboptimal conditions to these populations at their distributional edge. Leading– and trailing–edge populations may face different challenges; here red foxes, native to the boreal forest, are likely limited by abiotic factors, like the severity of winters, while Arctic foxes, native to the tundra, may be limited by competition with resident red foxes. Our objectives were to test the hypotheses that 1) movement strategy in both species is driven by the seasonal variability of food resources, but tundra winter severity limits the red fox only, and 2) the landscape heterogeneity of the study area relaxes competition between the two species by providing opportunities for resource segregation. The large proportion of adults from both species dispersing in winter suggested that winter conditions limits both species. However, among residents only red foxes substantially increased their Home range in winter, likely a consequence of higher energetic requirements than Arctic foxes. Both species were highly territorial, but red foxes did not exclude Arctic foxes by interference. In fact, we suspect that intraspecific competition in red foxes may be stronger than interspecific competition. Resident red foxes used slightly different habitats compared to Arctic foxes; specifically, access to forested habitat may be an important condition to survive over winter in this area when food is scarce. Current winter conditions may still prevent boreal–forest species from increasing their abundance on the tundra sufficiently to exclude endemics; co–existence with tundra dwellers may thus be possible.

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Different selection criteria may relax competition for denning sites between sympatric mesopredators on the low–Arctic tundra

Audrey MOIZAN, Chloé WARRET RODRIGUES, James D. ROTH

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Climate warming is favoring the expansion of non–native species onto the Arctic tundra, where they may compete with native species. In the harsh conditions of the Arctic tundra, sympatric red (*Vulpes vulpes*) and Arctic foxes (*Vulpes lagopus*) may compete over resources, such as good denning sites, which are important for their reproduction and survival. We studied den selection by red and Arctic foxes and their possible competition over this resource in an ecotone near Churchill, Manitoba, where forest, tundra and marine ecosystems merge. Specifically, we compared hypotheses to examine if foxes are choosing dens based on the proximity of specific habitats (and thus specific prey) or shelter quality, and how the two species differed. We further investigated possible interference by the larger red fox on the smaller Arctic fox by comparing spacing patterns between neighbors, and by quantifying the possible exclusion of Arctic foxes from dens favored by red foxes. Based on 11 years of occupancy data for 42 tundra dens, we determined that both red and Arctic foxes favored dens based on shelter quality, in both spring and summer. However, fine–scale mechanisms of den selection differed between species, which may promote co–existence. Based on the high proportion of dens with characteristics favored by red foxes available each year, we did not find evidence of exclusion of Arctic foxes by red foxes. Finally, spacing patterns suggested that foxes were more territorial in summer when pups are present. Taiga species settling on the tundra could thus coexist with their tundra competitors, at given density thresholds of both competitors.

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Competition between red fox and arctic fox at the southern edge of arctic fox range in North America

Glen BROWN

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The southern range limit of arctic fox in North America occurs along the southern coast of Hudson Bay, Canada. The status and vulnerability of this population is currently unknown, yet there is reason for concern due to evidence of ecosystem change from climate warming and presence of red fox as potential competitors. Northward range shifts associated with climate change may be particularly problematic for southern edge populations near Hudson Bay, which poses a substantial barrier to movement, and thus biodiversity conservation challenge for local jurisdictions. Given these unique conditions, we initiated den monitoring near Hudson Bay in Ontario. We located dens along 480 km of coastline in typical arctic fox denning habitat on inland beach ridges. The region is dominated by extensive wetlands and the beach ridges formed through isostatic rebound represent a unique and limited feature for denning in the otherwise wet landscape underlain by permafrost. Using information from trail cameras deployed at dens (2018–2021), we report species occupancy and reproduction, and evidence of competition with red fox. We interpret our findings in relation to landscape connectivity and food resources.

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Can intensive conservation measures on arctic foxes modify their competitive interactions with red foxes

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Over the last century, ecosystem perturbations have led to significant declines in abundance and geographical range for many species. In order to achieve efficient conservation, understanding the causes underlying species decline is important, but can be very challenging in some cases. In Fennoscandia, Arctic fox (*Vulpes lagopus*) populations have declined throughout the 20th century, reaching very low densities in the early 2000's. Two major causes have been identified to explain this decline: a climate–driven irregularity of the lemming cycle, and the northward expansion of red foxes (*Vulpes vulpes*). Studies in the Varanger Peninsula showed that competition with red foxes is an important factor limiting arctic fox use of space. Still, a red fox culling program didn't prove sufficient for the local arctic foxes to recover. Recently, intensive conservation measures, supplemental feeding and release of captive bred individuals, were added to the red fox culling, and resulted in a considerable growth of the local population.

Here we analyze how the presence of red foxes impacts arctic foxes' site use. In particular, we focus on how the monopolization of sites by red foxes is influenced by arctic fox population size and by the recent conservation measures. We test the hypothesis that these measures led arctic foxes to avoid red foxes to a lesser extent. To do so, we perform multi species occupancy models using a baited camera trap dataset. This survey spans over 17 years (2005 – present) including the red fox culling program (2005 – present) and the arctic fox reintroduction operation (2017 – present). With this project, we wish to assess the impact of these conservation actions and to propose further guidelines for the preservation of Arctic foxes.

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Annual variation in diet breadth and overlap between Arctic foxes and red foxes near treeline

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As the Arctic warms, expansion of southern species onto the Arctic tundra may threaten endemics through increased competition for prey and other resources. In northern Manitoba, Canada, red foxes historically were only found denning in the boreal forest, but their use of Arctic fox dens on the tundra has increased steadily in recent years, which may impact Arctic foxes through several mechanisms, including competition for prey. We examined variation in diet breadth and diet overlap between red foxes and Arctic foxes near Churchill, MB, on the west edge of Hudson Bay, where boreal forest transitions to Arctic tundra. We measured stable isotope ratios (C and N) of tissues collected from fox carcasses donated by local fur trappers from 2011–2018, reflecting winter diet. Isotopic niche breadth was smaller for red foxes than Arctic foxes in several years, suggesting Arctic fox diets may be more generalized than red foxes, contrary to predations. Niche breadth and overlap between Arctic and red fox varied among years but was unrelated to fluctuations in lemming density, which have damped in recent years. Overall, high niche overlap suggests these foxes use similar resources and could compete if fox densities increased, but variability in the availability of alternative resources may affect fox diet similarity and could relax competition in some winters. As red foxes continue to encroach onto the tundra, competition for scarce food sources in winter could exacerbate the impact of decreasing resource availability associated with changes in the cryosphere.

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Predator guild interactions in alpine and arctic tundra in relation to fluctuating prey

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Range expansion of boreal species into alpine and arctic tundra systems may threaten alpine species through competition and predation. In Fennoscandia, intensified competition from expanding populations of red foxes are considered a major threat to the recovery of the critically endangered arctic fox. Apex predators within the tundra guild, such as wolverine and golden eagle, may affect the apparent competitive asymmetry between red and arctic foxes, which may confound guidance of management and conservation of the endangered arctic fox. We used an extensive data set from baited camera traps, simulating carcass sites, across alpine and arctic tundra areas in Norway to evaluate co–occurrence and relative competitive strength between four focus species (red fox, arctic fox, wolverine and golden eagle) within the tundra predator guild. Overall, we found that arctic foxes were more likely to co–occur in areas with wolverine, and less in areas with golden eagle. Red foxes were positively associated with larger predators. Arctic and red foxes had a higher probability of co–occurrence when rodent abundance was low in the alpine tundra of central Norway, indicating increased levels of competition when resources were scarce. This was reversed for the co–occurrence of arctic foxes and golden eagles, indicating an increased risk of predation for arctic foxes in low rodent years. We found no discernable patterns in northern arctic tundra, likely as the number of arctic fox observations were very low. Our results contribute to the understanding of complex interactions of tundra predator guilds in relation to fluctuating prey and highlights the importance of a community and ecosystem focus when developing conservation and management action plans for threatened species.

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Arctic Fox predation on a Barnacle Goose Population

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In a time series of 32 year, we have monitored the effect of predation by Arctic Fox on reproductive success in a Barnacle Goose population near Ny–Ålesund, Svalbard. The goose population has increased and offers a rich potential summer food source for the foxes with their eggs and goslings. Fox activity on breeding islands is low, but when the eggs have hatched, foxes become the main predator of goslings grazing on the tundra.

Visual observation of individually marked goose family size made it possible to quantify the variation in daily survival rate of goslings. Over the years we registered variation in hunting tactics by arctic foxes. Fox predation did have a large effect on terrain usage of the geese, especially during the flightless moult period. Not only the daily survival rate of the goslings is affected by the fox but also growth rate of the surviving fraction of young geese. As small goslings are easier caught, the foxes also generate a pressure on early breeding by the geese. Both foxes and geese can use alternative food. For the fox these are eggs from arctic terns and waders. Geese have been switching to foraging on moss, lake algae, Lepidurus and sea weed. They accept lower quality food to reduce the risk of predation.

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Predator–prey interactions between the arctic fox and tundra nesting birds in space and time: first results of an ongoing circumpolar initiative

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In most arctic terrestrial ecosystems, the arctic fox is the main nest predator of tundra nesting birds. Although its population dynamics is often driven by direct interactions with lemmings or rodents, recent studies also highlight the major role played by arctic fox in modulating indirect interactions between its main prey (rodents), its alternative prey (e.g. geese) and shorebirds (referred as accidental/incidental prey).

Predator–prey interactions between predators (including the arctic fox) and 10 sandpiper species (*Calidris* spp.) are monitored since 2016 on a network of 20 study sites and six countries (the "Interactions Working Group"). At these sites, five standardized protocols are deployed to monitor (1) the relative abundance of predators, rodents (their main prey) and herbivores (alternative prey), (2) the predation pressure on tundra nesting birds (using artificial nest) and (3) the breeding success and incubation behaviour of sandpipers (using thermologgers placed in nests).

Since 2017, GPS–collars have also been deployed on foxes at several of these sites in order to improve our understanding of "fox–sandpipers" interactions in space and time ("landscape of fear" concept). For example, by comparing the respective behaviour of foxes (i.e., circadian rhythms, movement distances and speeds) and sandpipers (i.e., number, duration and timing of nest recesses) at different time scales (daily, seasonal or even interannual), our aim is to document what is the best timing for sandpipers to feed without facing higher predation risk from fox (predation rate of sandpiper nests increases with the number and duration of recesses). Similarly, by comparing foxes' space use (home ranges, Brownian bridge maps…) with the distribution and density of sandpiper nests, we aim at mapping fox predation risk spatially and to assess how Sandpipers cope with this risk (across species, years or sites). This presentation will present the first results of this joint initiative and its future challenges.

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2.4 Session IV – Movement and spatial ecology Chair: TBA

Dispersal abilities of Arctic fox juveniles and their implication for the conservation of Arctic fox populations in Scandinavia

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Long–term persistence of metapopulations in fragmented landscapes is dependent on connectivity among subpopulations. Dispersal rates can be influenced by geographic barriers, food availability and other environmental factors, as well as inter– and intraspecific interactions. Dispersal and settlement of immigrants is critical for the population viability of endangered species such as the Arctic fox (*Vulpes lagopus*), and a successful captive breeding program has been central to the national conservation strategy in Norway. A total of 318 foxes were released between 2006–2016 in mountain areas of Norway where the species had recently been extirpated or persisted in small numbers. In addition, 559 wild–born pups from 95 litters were individually marked between 2011–2018 in different release areas. Individual foxes were then tracked by observations of ear–tags, DNA identification from scats, PIT–tag detections at feeding stations, and recovered mortalities. We built mark–recapture models to estimate the probability of dispersal of foxes from release or birth sites, and to compare movements between captive–bred vs. wild–born individuals. Dispersal typically took place during the winter. Released foxes were detected 23.3 km away from release sites (± 37.9SE, range: 0 – 219.2, n=194), whereas wild–born juveniles moved 7.2 km away from the natal den (± 27.7, range: 0 – 431.1, n=312). A total of 46 foxes released from the captive breeding programme and another 51 wild–born foxes were recorded as breeding in the wild between 2008 and 2017. First breeding attempts averaged 29.9 ± 43.9 km from release sites (range: 0 – 174.7) and 13.8 ± 28.6 km from birth sites (range: 0 – 190.8). Our estimates of apparent survival indicated that juveniles had a higher dispersal rates than adults, and that the probability of dispersal was higher in years with low lemming numbers. Systematic monitoring of arctic foxes at a large geographic scale revealed their remarkable capacity for long–range movements.

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Home ranges and movements of Arctic fox (*Vulpes lagopus*) in the North of Western Siberia, Russia

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In 2020–2021 in the North of Western Siberia, Russia, GPS–Iridium collars were fitted to 18 Arctic foxes (*Vulpes lagopus*) on the South Tambey Gas–Field near the settlement Sabetta on the Yamal Peninsula and to five Arctic foxes on Untrennee Gas–Field on the Gydan Peninsula. GPS tracking was conducted to determine daily and seasonal movements of foxes, their home range sizes and territorial behavior. Arctic fox collaring was carried out using satellite transmitters that send location data and temperature. For the first time in the Russian Arctic, accurate data about winter movements and long–distance dispersal of Arctic foxes was received. The study revealed the importance of human settlements for Arctic foxes from December to May both in 2020 and 2021. Most of the Arctic foxes regularly moved between their dens and human infrastructure. Six Arctic foxes lived among infrastructure objects year–round. The sizes of Arctic fox home ranges were calculated and there were not significant differences over 2 years, despite the different density of their main prey – small rodents' population (high in 2020 and low in 2021). Arctic foxes lived in their home ranges for 7–8 months, so we suggest that during this period their diet composition mainly consisted of small rodents, birds and bird's eggs. The home ranges of most Arctic foxes did not overlap. Four Arctic foxes among 23 left places where they were collared and did not come back, covering a cumulative distance from 300 to 5000 km. Two of them used the sea ice as a bridge during dispersal. The maximum movement rate for these foxes was 154 km/day and occurred while crossing the ice on Gydan and Mammoth bays. One of the Arctic foxes covered a greater distance during the night, which could be associated with contrast in snow hardness during different times of the day.

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Linking melting sea ice and future genetic isolation of arctic foxes: A spatially explicit individual–based approach

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Climate change is an overwhelming phenomenon that alters the interaction between many species and is transforming ecosystems worldwide. The Arctic is warming faster than any other region in the world. As a result, sea ice cover is decreasing, which also reduces the connectivity of animal habitats. The Arctic fox (Vulpes lagopus) has a circumpolar distribution with small genetic divergence between populations connected by sea ice. This species uses sea ice to move between landmasses. Arctic foxes equipped with GPS collars have shown movement of individuals on the ice to cover large distances over short periods of time. These observations support having low genetic differentiation. We hypothesized that global warming would lead to a gradual spatial separation of Arctic fox populations that were once connected. To do so, we used a spatially explicit individual model, parametrized with evidence of ecology and movements of Arctic foxes. We simulated virtual individuals that can move, reproduce and transmit alleles on a map representing Arctic regions. The virtual map simulates the gradual melting of Arctic ice through the use of predictive climate models. From the genetic differentiation in simulated Arctic foxes, resulting from this gradual decrease in pack ice, we can infer threats affecting this species like consanguinity and genetic drift in a rapidly changing Arctic. This study is of particular interest for the conservation and future of the Arctic fox.

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How does prey availability shape predator territories?

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Territoriality allows individuals to gain exclusive access over resources such as food or mate but comes at the costs of defending it. Territory size is therefore expected to vary according to the trade–offs between the cost of defense (e.g. number of competitors, energetic demands to patrol) and the benefits of gaining monopoly over resources (e.g. density of resource, spatial predictability). Using ARGOS data collected on Bylot Island for 8 years, we investigated how lemming and goose density influence territory size in Arctic fox. We found that territory size increased with declining goose availability. Territories were also larger at low lemming density but only in places where geese were unavailable. We present those results in the context of prey spatiotemporal predictability and discuss their implication in terms of predation risk for shorebirds and other accidental prey species.

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Habitat use and movement patterns in a strict lemming fox population – GPS–collar data from Scandinavia

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For territorial animals, territory characteristics such as vegetation types, topography and proximity to risky habitats affect how individuals allocate time for foraging, juvenile care and territory maintenance. Territory quality can therefore have a large effect on survival and breeding success, and likely affects movement patterns and territory use across spatial and temporal scales. The Scandinavian arctic fox population is on the fringe of the species distribution range and isolated to mountain tundra areas, forming islands surrounded by forests. In contrast to the long–range across sea–ice movements observed in individuals in Canada and Svalbard, Scandinavian foxes are generally regarded as limited in their movements outside their local mountain area, as implied by genetics studies and sightings of tagged individuals. However, detailed information on movement patterns and habitat use during and outside the breeding season was not available until recently. Based on the first GPS–collar data recorded from the Scandinavian arctic fox population, we have studied the habitat use, territory size and movement patterns in 13 breeding and non–breeding individuals, during and after the breeding period. Breeding individuals showed a strong fidelity to their den sites, and feeding stations appeared to be monopolised as spatial overlap was small around those. All individuals but one had no or limited movements outside the mountain tundra habitat, stressing the importance of forested areas as potentially strong dispersion barriers between the fragmented Arctic fox sub populations in Scandinavia. We also constructed a habitat distribution model based on collar data and compared it with a den location based model. Our data adds to a growing body of spatial data collected from different arctic fox populations living in contrasting environments. And we believe that such studies give the arctic fox a strong potential to be a model species for the study of ecosystem effects on spatial behaviour.

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2.5 Session VI – Physiology and genetics
Chair: Øystein Flagstad

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

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Sub arctic tundra populations of arctic fox are under increasing threat of localised extinction. This means that captive breeding for release programmes are becoming an essential component of long-term recovery efforts for this species. Thus, it is important that stakeholders are 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) have been identified as suitable targets for such genetic conservation in breeding programmes. The MHC is an essential component of the immune system in all mammals and drives the immune response. Studies in many species have established strong associations of specific MHC alleles with many autoimmune diseases, other genetic diseases and response to infection. The MHC is the most polymorphic gene complex in the genome, and the extent of variation has been shown to contribute to species survival: higher diversity is linked to better survival. DNA was extracted from blood or muscle samples for 200 arctic foxes from five different countries. Previously published data on the variation in Vula-DRB1 and Vula-DQB1 in the arctic fox suggest the existence of at least 12 different alleles at each locus. However, the sequences are partial sequences and do not cover all the polymorphic positions in exon 2.

We have combined these partial sequences with complete exon 2 sequence data, using new primers, to create a database of arctic fox Vula-DRB1 and DRA alleles. For comparison, we have data for Vuvu-DRB1 and DRA alleles found in >300 red foxes from seven different countries.

We have identified >25 Vula-DRB1 alleles, of which eight match published partial 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 5-12, but these do not correlate with population size (n=5-52), suggesting some populations are much more diverse than others. Interestingly, one allele found in arctic foxes from Sweden, was also found in red foxes from several European countries. Another common arctic fox allele was also found in Alaskan red foxes. Preliminary data for Vula-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 other canid species, including the red fox. MHC allele profiles vary between different populations of Arctic fox. We have also shown that there is allele sharing between arctic and red foxes.

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Inbreeding and genomic erosion in northernmost Scandinavia

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Small and isolated populations are at high risk of genomic erosion following inbreeding, accumulation of deleterious alleles and reduced evolutionary potential. Following a severe demographic bottleneck and reduced gene flow from the large and outbred Siberian population, the Scandinavian arctic fox has become increasingly isolated over the last century. Furthermore, local declines and climate change has increased fragmentation within Scandinavia. To investigate how low population size and isolation have influenced the genomic composition in northernmost Scandinavia, we have sequenced complete genomes from 43 arctic foxes and assessed their level of genome–wide heterozyosity, signatures of inbreeding (ROH) and frequency of loss of function mutations. This study demonstrates that northern Scandinavia displays signatures of elevated levels of recent inbreeding, lowered genomic variation and accumulation of loss of function mutations that can impact on population viability. For long–term persistence of the entire Scandinavian population and to mitigate genomic erosion, it is of fundamental importance to promote connectivity and gene flow, both within Scandinavia and with Siberia.

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Genomic consequences of inbreeding and gene flow in the Swedish arctic fox

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Inbreeding depression has been documented in various fitness traits in a wide range of species and taxa, however, the mutational basis is not yet well understood. We investigate how putatively deleterious variation influences fitness and is shaped by individual ancestry by sequencing multiple complete genomes of a natural arctic fox (Vulpes lagopus) population subjected to both inbreeding depression and genetic rescue. We found that individuals with high proportion of loss of function mutations (LoFs), which are predicted to exert a strong effect on fitness, generally produced smaller litters, lived shorter lives and had lower lifetime reproductive success compared with individuals with lower proportion of LoFs. However, we found no association between moderately deleterious variation (i.e. missense mutations) and fitness. Moreover, we found that immigrant foxes had high genetic diversity but introduced several novel deleterious mutations into the population, and their descendants had on average 4% higher proportion of LoFs compared with native individuals. However, another Swedish subpopulation that also experienced recent gene flow did not increase in amount of deleterious mutations post immigration. Our results demonstrate that homozygosity of strongly deleterious mutations can be an important cause of inbreeding depression in wild populations and that effects of gene flow are highly context dependent. These results mark an important step towards making more informed decisions using applied conservation genetics.

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Tooth wear and breakage patterns reflect diets of arctic foxes.

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We here present a preliminary study of tooth wear (macro–scale and microscopic) and breakage for arctic foxes from the Yamal Peninsula of Russia (n = 78 individuals). Microwear patterns change over weeks whereas gross wear and tooth breakage accumulate over a lifetime, so these diet proxies reflect different temporal scales of food choice. However, both reflect relative consumption of hard (e.g., large mammal bone) and soft foods. Specimens were parsed by location (northern versus southern Yamal) and by trapping period (peak rodent density, 1983, and low rodent density, 1981/2007) to assess effects of varying food availability over space and time on teeth.

Levels of gross wear and tooth breakage were assessed relative to canine pulp chamber area (as a control for age) in ANCOVA models. Results indicate significantly more gross tooth wear and breakage in the north than the south. This is consistent with more consumption of hard foods (e.g., reindeer bone) in the north. There were no significant differences in gross tooth wear or breakage between individuals sampled during rodent peak and trough periods. Microwear, however, did differ significantly between rodent peak and trough periods in the north, but not in the south. There was more dispersion in texture complexity, including higher values, in rodent trough than peak periods in the northern sample. This again suggests a greater reliance on hard foods in the north, but only when rodents are not plentiful.

These results in combination are consistent with foxes scavenging more reindeer bone (or perhaps hunting more calves) in the north than the south during rodent–poor years. This might be explained by a greater availability of alternative small prey (e.g., ptarmigans, hares) in the south. This study suggests that dental wear and breakage hold potential as valuable proxies for studying food choice in historical arctic fox populations.

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Activity budget and ontogeny of behaviours in captive–bred juvenile arctic foxes

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Intraspecific comparisons in behaviours and their repeatability in a juvenile period is important to understand. The ontogeny of juvenile behaviour might be consistent through time or show high flexibility. In this study, we observed 135 juvenile arctic foxes (8 times per individual) in a captive breeding programme to produce an ethogram and activity budgets of juvenile arctic foxes in 2015–16 and 2018–19. We then compared behavioural variation in juveniles according to sex and its temporal change with ontogeny. To examine between–season behavioural repeatability over a juvenile period, we calculated repeatabilities using repeated observations of the same individuals (n = 45) in the summer and in the autumn in 2015–16. Through the behavioural observation, juvenile arctic foxes showed a high frequency of locomotion (37% in the summer, 44% in the autumn) in their activity budgets, followed by investigation (17% in both seasons), rest (14% in the summer, 10% in the autumn), and play (14% in the summer, 10% in the autumn). Males played more while females were more vigilant, but the other behaviours showed no sexual differences. Furthermore, juveniles did not show high repeatability in their behaviour except that locomotion showed moderate repeatability. We also found that males had slightly higher repeatabilities in almost all behaviour categories than females had. Our study suggested that juvenile arctic foxes have rather flexible behaviours over ontogeny with some marginal differences in activity budgets, and the repeatabilities of state behaviours between sexes.

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Temporal trends of mandibular shape in the Icelandic arctic fox (*Vulpes lagopus*)

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Icelandic arctic foxes are geographically isolated, enabling morphological comparisons at the population–level without genetic migration from non–Icelandic arctic fox populations. Within the Icelandic fox population, two ecotypes are distinguished by their feeding ecology and range. The coastal ecotype relies on a heterogeneous, marine–based diet, while the inland ecotype relies on bird species, especially rock ptarmigan. Past work has found that different foraging behavior, rather than distance, presents as the factor that most impedes gene flow for the Arctic fox. Divergent foraging strategies have been linked to morphological changes in regions of the skull and mandible involved in feeding in other arctic fox and red fox (*Vulpes vulpes*) populations. However, the link between jaw morphology and feeding ecology has not been investigated among the two Icelandic ecotypes. We obtained mandibles from the Icelandic Institute of Natural History, which houses a collection that spans four decades. Using geometric morphometrics, we assessed overall mandibular shape from 290 foxes belonging to both Icelandic ecotypes. Functional outputs (bite force at the carnassial, masseter force, gape) were approximated using linear measures. We found differences in mandibular shape ($p<0.001$) between the inland and coastal ecotypes in anatomical regions that are functionally important for chewing. The overall degree of these differences between ecotypes fluctuated throughout time, and the ecotypes were more distinct during the 1980's and the early 2010's than during the intervening decades. As with the overall shape, the estimated functional outputs of each ecotype varied through time. This suggests shape differences associated with the separate diets of each ecotype may be sensitive to perturbations in diet composition, and that decadal shifts in foraging strategy may be observed through mandibular shape change. Ultimately, Icelandic arctic foxes (*Vulpes lagopus*) provide a unique opportunity to examine the interactions between feeding ecology and a mammalian population's mandibular morphology through time.

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2.6 Session VI – Management and conservation Chair: Rolf Anker Ims

From captive to free – survival and reproduction in Arctic foxes

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Anne–Mathilde THIERRY, Torbjørn ERGON, Øystein FLAGSTAD,
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For species threatened by extinction, captive breeding programmes can represent a last resort for conservation and restoration of wild populations. Successful reproduction in captivity and reintroduction to wild populations can however be challenging. Since the production of young is critical to the success of such conservation initiatives, an understanding of factors that influence reproductive success is vital. Individuals born and raised in captivity are exposed to selection pressures that differ from wild populations which can result in reduced fitness for animals breeding in captivity, and also post–release. The causes of reduced fitness are often elusive, but may arise through environmental effects of captive rearing, relaxed natural selection, unintentional domestication selection, or inbreeding. The main strategy to mitigate such effects is partly to use wild–caught breeding animals and limit the number of generations that captive animals are used in breeding programmes. Here we report on reproductive success in captive arctic foxes and how this is influenced by characteristics of the parents, including age and number of generations in captivity. Female age had the most significant impact, with litter size peaking at the age of four years. For females older than four years, the data indicate reproductive senescence and a decline in litter size with age. We found no effect of the number of generations in captivity on reproductive success at the breeding station or on post–release survival and reproduction. However, effects of captive breeding may be subtle and difficult to detect. Furthermore, we estimated survival and reproductive success of captive–bred foxes post–release, and compared this to wild–born foxes, but found no differences.

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Captive breeding as a conservation tool – experiences from Norway's Arctic fox captive breeding program

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In 2000, there were as few as 40–60 Arctic foxes remaining in Scandinavia. Urgent conservation actions were required to save the species from local extinction, and a captive breeding facility was consequently established in central Norway in 2005. The long–term project rapidly became a central pillar in regional conservation efforts and continues to do so today. Following the release of the first captive–bred Arctic foxes in 2006, a total of 460 arctic foxes have been reintroduced into the wild. In combination with active management interventions, the programme has facilitated the reestablishment of three locally extinct arctic fox populations and strengthened numbers in numerous others. The Norwegian arctic fox population has displayed a stable growth rate over recent years and now numbers ca. 300 individuals. In this presentation, we will provide an overview of the captive breeding programme and specifically provide a behind–the–scenes look into the operation of the breeding station. Principles guiding management decisions, ranging from selecting breeding animals to selecting release locations, as well as the challenges encountered at the breeding facility, will be presented and discussed. Data obtained at the breeding station and following release into the wild provide a valuable basis from which the effectiveness of management interventions can be investigated.

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Status and conservation goals for the critically endangered Arctic fox in Scandinavia. Where are we now and when is mission completed?

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The arctic fox is still listed as endangered, despite protection in Scandinavia for almost 100 years. Intensive conservation actions have been implemented over 20 years; red fox culling, supplemental feeding and release of captive breed Arctic foxes. Systematic monitoring of the subpopulations in all three countries has revealed that the total population has increased from less than 50 to now soon 500 adult foxes, revealing that the conservation program has been a success. Sub–populations are re–established, and the connectivity is about to be restored in parts of the species distribution. We present current status of the Fennoscandian population and how the program was built.

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 could still not be considered as viable in long term. Based on best available knowledge we have calculated the potential carrying capacity of different subpopulations, to define regional goals. Some subpopulations with released cubs, have a high growth rate while others have a lower growth rate compared to subpopulations that achieve supplemental feeding and/or red fox culling.

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The effect of management actions on the effective population size in the Scandinavian arctic fox (*Vulpes lagopus*) population

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The effective population size Ne is an importnat determinant of the loss or maintainance of genetic diversity, which is important for population persistence. Ne is normally correlated to the census size, but due to flucuating population size, skewed sex ratio, population substructure and/or variance in reproductive success, the effective size is typically lower than the census size in natural populations, commonly with a ratio between 1:4 and 1:10. In this study, we assessed effective population size of the Scandinavian Arctic fox. This population was on the verge of extinction by the turn of the millenium, but started to recover after the implementation of a variety of conservation actions such as supplemental feeding, red fox culling and captive breeding and release. We demonstrate increasing effective populations sizes in all subpopulations analysed during 2008–2015, as expected given the increase in census size. Looking at the entire metapopulation, however, the increase in effective population size is less pronounced. At present the effective size of the entire metapopulation is between 1:8 and 1:10 of the cencus size. The low ratio can be attributed to the recent situation of small isolated subpopulations with little gene flow across the metapopulation. Recently, however, gene flow has been increasing, restoring metapopulation dynamics. Over time, this will reduce population substructure, which in turn will reduce the difference between effective and census size. The action plan for the Scandinavian arctic fox population has a long–term goal of 2000 adult arctic foxes. Following the rule of thumb for long–term viability in a population (Ne = 500), this would require a ratio of 1:4 between effective and census size. Indeed, restoring metapopulation dynamics with increasing gene flow is a pivotal step towards this goal.

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Intensive conservation measures decouple arctic fox reproduction from lemming dynamics: the case of Varanger Peninsula

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The arctic fox metapopulation in Fennoscandia has been critically endangered over a century, but due to thorough research and intensive conservation measures it has now started to slowly recover. Whereas populations in central Scandinavia have shown a positive development, in the northern part of the country, formerly a stronghold for arctic foxes, the population has remained critically low until recently. On Varanger Peninsula at the northeastern tip of Scandinavia, research has identified that irregularity of lemming cycles and high red fox abundance are two major drivers of the critical state of the local arctic fox population (see Ims et al. 2017 Polar Research 36, 8). Despite implementation of intensive red fox culling as a management action since 2005, there were probably only 2 arctic foxes present on the Peninsula in 2017. We hypothesized that absence of lemming peaks and an initially very small arctic fox population (i.e. demographic stochasticity) contributed to the lack of a response to the culling action. Consequently, two additional management actions were implemented to address these hypotheses in 2017. Supplemental feeding was implemented together with the release of 65 captive bred arctic fox pups on Varanger over three years (2018–2020). Preliminary results show a positive development resulting from these actions. The arctic fox population has increased steadily and reached an estimate of 33 [95% CI 23–46] in 2021. The number of litters born on the peninsula has increased since 2018 and reached the highest number observed during the project in 2021 with seven litters. Interestingly, the litter production, which previously was strongly linked to lemming dynamics, appears presently not to be so. Hence, the supplementary feeding seem to have decoupled the reproductive output of arctic fox from its major natural driver; i.e. the lemming cycle and possibly also relaxed the competitive pressure from the red fox.

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2.7 Session VII – Life–history and Demography Chair: Eva Fuglei

Food limitation or life–history trade–offs? Reproductive output of Arctic foxes feeding on a cyclic prey

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Phenotypic plasticity of breeding parameters is particularly important in fluctuating environments, where individuals may vary reproductive investment depending on the conditions. The Arctic fox adopts different reproductive strategies depending on its prey base and, in populations relying on cyclic small rodents, reproductive output was shown to be determined by both food abundance and rodent phase–dependent adjustments. Notably, during the increase phase of the rodent cycle, an over–production of pups in relation to food abundance was observed in Fennoscandia. High offspring value of pups born when rodent availability is improving may increase reproductive investment. We confronted the food limitation hypothesis to the life history hypothesis in the Canadian Arctic, using a natural setting where, in addition to a cyclic prey (lemmings), some foxes had access to a nesting goose colony. For foxes with or without access to colony, we evaluated how the rodent cycle and density influenced (1) date of pup emergence, (2) litter size and (3) pup survival during summer. We found that pups emerged much later in dens located outside of the colony, except during a lemming peak phase where they emerged as early as those in the colony. Litter sizes increased with lemming density for dens in the colony, but surprisingly, litter sizes of dens outside of the colony remained stable and were not influenced by that factor. After controlling for the effect of lemming density, there was still an additional effect of lemming phase, with notably litter sizes during increase and peak phases being similarly high. Finally, pup survival during summer improved with increasing lemming densities, but with no influence of the colony or lemming phase. Overall, our study showed that Arctic foxes generally adjusted reproductive parameters depending on lemming availability but also showed some phase–related responses, while the goose resource seemed to have a limited impact.

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Contributions from terrestrial and marine resources stabilize predator populations in a rapidly changing climate

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Climate change has different and sometimes divergent effects on terrestrial and marine food webs, and in coastal ecosystems, these effects are tightly interlinked. Responses of opportunistic coastal predators and scavengers to climate change may thus be complex and potentially highly flexible, and can simultaneously serve as indicators of, and have profound impacts on, lower trophic levels. Gaining mechanistic understanding of these responses is therefore important, but often not feasible due to lack of long–term data from marked individuals. Here, we used a Bayesian integrated population model (IPM) to elucidate the effects of arctic warming and concurrent changes in terrestrial and marine resource availability on population dynamics of the opportunistic arctic fox (*Vulpes lagopus*) in Svalbard. Joint analysis of four types of data (den survey, age–at–harvest, placental scars, mark–recovery) revealed relatively stable population size and age structure over the last 22 yr (1997–2019) despite rapid environmental change linked to climate warming. This was related to the fact that terrestrial resources (reindeer carcasses, geese) became more abundant while the availability of marine resources (seal pups/carrion) decreased, and was driven by divergent trends in different vital rates (e.g., increased pregnancy rate but decreased pup survival). Balanced contributions of survival vs. reproduction and of immigration vs. local demography further stabilized population size. Our study thus sheds light on the mechanisms underlying population dynamics of opportunistic carnivores exploiting terrestrial and marine resources and suggests that exploitation of resources across different ecosystems can buffer predators against climate change. Additionally, it highlights the large potential of IPMs as tools to understand and predict the effects of environmental change on wildlife populations, even when data on marked individuals are sparse.

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The dark side of the moult – Phenological plasticity and intraspecific variations in white and blue morph Arctic foxes

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With climate change driving a shift in seasonality, characterising the capacity of species to rapidly adapt is essential to assess potential effects on population dynamics. In the Arctic, seasonal moulting provides year–round camouflage and thermal protection for the well–adapted Arctic fox (Vulpes lagopus). However, increased seasonal variability can lead to phenological mismatch. The goal of this study was to investigate whether Arctic foxes can adjust their winter–to–summer moult to match local environmental conditions. Additionally, we explored differences between foxes of the white and blue morphs. Using camera trap images spanning an eight–year period (2011–2018), we quantified the timing and rate of fur change in a polymorphic subpopulation in south–central Norway, and found that seasonal snow cover duration and temperature governed the timing and rate of the spring moult. Decreasing temperatures and longer snow seasons led to a later onset and longer moulting duration, with up to a six–week difference in inter–annual mean population completion dates for the years where climatic conditions contrasted the most. Moreover, winter–white individuals moulted earlier than winter–brown in years with shorter periods of snow cover and warmer temperatures, providing the first evidence for variations in the moulting phenology of white and blue Arctic foxes. Our results suggest that the species shows plasticity in the timing and rate of its spring moult, and provide insights on the major evolutionary forces at play in seasonal fur change. We will furthermore discuss the importance of integrating morph–based differences in future management strategies of polymorphic populations.

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2.8 Session VIII – Diseases, parasites, and pollution
Chair: TBA

Phylogenetics and genomic characteristics of canine distemper virus in Arctic foxes

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Canine distemper – a viral disease with high mortality and no cure – poses a major threat to wildlife, especially endangered species or subspecies such as the Scandinavian Arctic fox. Canine distemper epidemics have decimated several endangered populations, such as lions in Serengeti, Island foxes, and black–footed ferrets in Wyoming. It is distributed globally and infects a wide range of host species. Although a vaccine is available, the viral strains observed in wildlife differ substantially from the vaccine strain, making the vaccine less effective against wildlife strains. The Arctic fauna—already vulnerable due to climate change and habitat loss—could benefit from studies on canine distemper virus (CDV) circulating in the Arctic and neighboring regions. However, little is known about CDV in these regions, partly due to difficult field conditions for data collection. We managed to obtain several tissue samples from Arctic foxes and other canids in Alaska from different outbreak years (2011–2021). We extracted and sequenced CDV genomes, performed phylogenetic analyses, and compared the observed wildlife strains with vaccine strains, and other published strain sequences from around the world. Here, we present CDV sequences found in the Arctic foxes, their evolutionary relationship with other strains found globally, and important characteristics such as genetic variability. This is useful for informing effective vaccination strategies to protect wildlife populations—especially vulnerable Arctic fox populations—from epidemics that can exacerbate their threatened or endangered existence.

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Crossing Species and Borders: Bartonella transmission between prey and Arctic foxes in the high Arctic

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Bartonella are gram–negative, intracellular bacteria that are transmitted by direct contact with infected animals and blood–feeding arthropods. Three species of Bartonella (*B. vinsonii berkhoffii*, *B. rochalimae*, and *B. henselae*) were detected in the blood of live captured Arctic foxes (Vulpes lagopus) in the remote terrestrial Arctic ecosystem at Karrak Lake, Nunavut. All three species were also identified in fleas (Ceratophyllus vagabundus vagabundus) that parasitize the nests of migratory geese, suggesting that transmission may occur between birds, their ectoparasites, and foxes during nest predation. Our study aims to further characterize Bartonella that may be transmitted to foxes by identifying species in rodent prey, vectors (rodent fleas, avian fleas, and fox lice) and migratory geese. Conventional PCR using primers targeting the 16S–23S rRNA intergenic transcribed spacer region revealed Bartonella DNA in 42% of nest fleas (*B. vinsonii berkhoffii* and *B. rochalimae*; n=10/24; CI95 24–61), 70% of flea pools from red–backed voles (*B. rochalimae* and *B. grahamii*; n=7/10; CI95 40–89), 20% of red–backed voles (*B. grahamii*, *B. vinsonii* subsp. *berkhoffii*, *Bartonella* sp. BvS12; n=4/20; CI95 8–42), and 2% of Ross's geese (*B. vinsonii berkhoffii*; n=1/42; CI95 0.4–12). *Bartonella* DNA was also found in two pooled samples of sucking lice collected from Arctic foxes trapped in Svalbard (Norway), though no match could be found for the species in GenBank. These findings indicate that geese and their associated ectoparasites serve as migratory hosts and vectors, bringing *Bartonella* spp. from southern latitudes to northern nesting grounds. Detection of endemic species of *Bartonella* in rodents and their associated ectoparasites suggests that these bacteria may also be transmitted between foxes and rodents during predation. Finally, the detection of a unique *Bartonella* spp. in fox lice indicates that foxes may play a role in transmission as well, moving infected ectoparasites between fox populations during long distance dispersals.

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Foxes (Vulpes spp.) consuming more migratory and marine food sources have higher exposure to the parasite *Toxoplasma gondii*

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Predators in food webs are valuable sentinel species for zoonotic and multi–host pathogens such as Toxoplasma gondii. This protozoan parasite is commonly found in warm–blooded vertebrates, and can have serious adverse effects on immunocompromised hosts and foetuses. Understanding the spread of *T. gondii* in northern ecosystems is of interest to elucidate the ecological drivers of infection. As sentinel species, foxes could give us a better idea of *T. gondii* distribution and help us understand how it persists and spread in this ecosystem through trophic links. We generated baseline data on *T. gondii* amongst foxes from Nunavik, northern Québec (Canada), and looked at trophic relationships between foxes and their prey species to search for routes of transmission for *T. gondii* in northern food webs. Red (*Vulpes vulpes*) and Arctic fox (*Vulpes lagopus*) carcasses (n=239) were collected by local trappers and collaborators during winters of 2015–2019. We used a combination of magnetic capture PCR and enzyme–linked immunosorbent assay to detect current infection status and previous exposure of *T. gondii* in heart and brain of foxes. We linked infection status of foxes with diet composition derived from stable isotope analyses. We observed a significant difference in exposure to *T. gondii* in foxes from eastern Hudson Bay and southwestern Ungava Bay: 29% (n=154, CI95%: 22–36) compared to 65% (n=74; CI95%:54–75), respectively. Stable isotope mixing model analysis showed that infected foxes had a higher probability to consume marine and migratory food sources. These results support the hypothesis that marine food sources could be a significant contributor to the transmission cycles in northern regions. Our research throws light on the role prey species could play in persistence of *T. gondii* in the North, and thus, aids in informing future risk assessments to determine the potential human and animal health risks associated to *T. gondii* infection.

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Prevalence and distribution of *Echinococcus multilocularis* in arctic foxes (*Vulpes lagopus*) in Svalbard.

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The zoonotic tapeworm *Echinococcus multilocularis* (Em) was first detected in Svalbard in 1999. This parasite has an indirect lifecycle requiring an intermediate rodent host in addition to a canine final host. In the present study, we analysed arctic fox small intestines for this parasite using a segmented sedimentation counting technique. This project was part of the larger EU OHEJP project MEmE.

Arctic foxes (n=178) were caught in baited traps during winter (2019–2021) and stored at minus 80 ºC for seven days to inactivate Em eggs and adults. The small intestine was then removed and divided into four equal segments. A 20 % subsample of the contents from each segment was analysed by stereomicroscopy for Em. If positive, the total contents of the segment were investigated and the total number of adult Em recorded. The presence of other tapeworm species was noted.

Five of the foxes had adult Em in one or more of the intestinal segments (2.8 % [95 % confidence interval (CI) 0.9–6.4]). The positive foxes were from Colesbukta, Bødalen, Grumant, Ispallen and Sassendalen. The fox from Ispallen had over 80000 adult Em, the foxes from Bødalen and Sassendalen had 5000 whilst the remaining two had around 400. The parasite burden was in general highest in the most distal segment (S4) with a trend of lower burdens closer to the stomach. Other tapeworm species were recorded in 62 of the fox intestines (34.8 % [95 % CI 27.8–41.8]) but were not identified further.

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3 Abstracts poster sessions

3.1 Session I – Population status and monitoring

Poster 1

Arctic fox monitoring in a polar desert: new insights from Alert, the northernmost Arctic fox study area

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Polar deserts, characterized by barren grounds and continuous permafrost, are the most extreme environments in the Northern Hemisphere. Due to their remoteness and thus considerable logistical challenges, very few study sites are located in this biome. However, despite the scarcity of their biodiversity, polar desert landscapes are the most representative of the High Arctic. Our newly established study area, Alert (82°30' N, 62°20' W), is located at the northern tip of Ellesmere Island in the Canadian Arctic Archipelago, only 817 km from the North Pole. Since the 1950s, a Canadian Forces Station (CFS) and a meteorological station have been operating year–round at Alert, making it the northernmost permanently inhabited settlement in the world. Studied in partnership with 8 Wing Trenton Environmental Management, Department of National Defence (DND), our study area encompasses the total DND property around CFS Alert (163 km2). Since 2018, we have implemented several annual monitoring protocols, including Arctic fox den search and monitoring. In 2019 (a lemming peak year), we found five active fox dens (four litters) and one active wolf den (one litter). Three fox litters were a mix of blue and white pups, indicating a proportion of at least 37.5% (3/8) of adults being of the blue morph. This proportion is very high for Canada and may be explained by the proximity of Alert to western Greenland, where the blue morph is relatively more common. In addition to the typical Arctic fox–lemming relationship, predator–prey interactions at Alert include an Arctic wolf–Arctic hare relationship, thereby introducing potential wolf–fox intraguild competition and predation, as well as lemming–hare apparent competition resulting from shared predation. This new study site, accessible year–round, will help improve our understanding of Arctic fox winter ecology, population connectivity, predator–prey interactions and ecosystem functioning of a polar desert.

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3.2 Session II – Ecosystem approaches

Poster 2

Arctic Fox Gardens: Vegetation and Soil Nutrient subsidization on dens

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Many wildlife populations are currently undergoing dramatic global declines resulting in major interference with ecosystem functions. An often–overlooked contribution of animal populations to these functions is their capacity to shape environments via the relocation of nutrients. This is of particular interest, as at higher latitudes effects of climate change are already pronounced, and defaunation is thriving.

This study, therefore, investigates the influence of the arctic fox (*Alopex lagopus*) on vegetation and soil in a nutrient–poor habitat. Through extensive activity (scats, burrowing, and discarding of unfinished prey items), they potentially affect soil nutrition and vegetation on den sites. In Iceland, vegetation and soil nutrients were sampled at both dens and control plots within 3 km of the coast. Analysis of soil nutrients (Nitrate and Phosphate) was conducted using quick test stripes, while vegetation was sampled using the Braun–Blanquet technique. Plant species communities were modelled via multivariate, model–based ordination (Bayesian estimation).

Arctic foxes had a significant effect on soil nutrients and vegetation. Dens inhabited a larger number of species, more herbs, and grasses, and an altered species community when compared to control plots. Nitrate levels were remarkably higher on den sites soils compared to non–den areas. These results suggest that arctic foxes provide nutrient subsidies to their denning areas resulting in a more complex and diverse plant community. The reliance on marine resources in coastal fox populations, suggests that a marine–to–terrestrial nutrient flow is facilitated by this terrestrial mammalian carnivore. This peculiar phenomenon highlights the importance of arctic foxes and other predatory species for the maintenance of ecosystem functions in threatened high–latitude arctic habitats.

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3.3 Session III – Predation and competition

Poster 3

Resource partitioning among the vertebrate scavengers of Svalbard

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Dead organic matter or detritus is a central ecological resource in food webs, which promotes biodiversity and ecosystem stability. Dead animal matter, or carrion, is a distinct component of this detritus pool, which has a large impact on ecological communities. This impact is highly contextual, and depends on temperature, terrain, scavenger richness, and carrion availability across the landscape. However, our knowledge on carrion availability and use in the Arctic tundra is very limited.

We aim to assess how resource partitioning among vertebrate scavengers mediates carrion effects on vegetation and soil microorganisms in the Arctic tundra of Svalbard. Our study system is relatively simple, with only two resident herbivores – the Svalbard reindeer (*Rangifer tarandus*) and the Svalbard rock ptarmigan (*Lagopus muta hyperborea*), and a scavenger community that comprises arctic foxes (*Vulpes lagopus*), glaucous gulls (*Larus hyperboreus*), great skuas (*Stercorarius skua*), and polars bears (*Ursus maritimus*). Our study focuses on reindeer cadavers. Reindeer mortality peaks during winter, when arthropod and fungal activity is decreased, and most carrion is available for consumption by vertebrate scavengers. We have experimentally deployed entire fresh–frozen reindeer cadavers along a coastal–inland gradient and monitored scavenger activity using time–lapse cameras. We deployed 20 cadavers in late winter 2022 and will repeat this in 2023 and 2024. We conduct vegetation and soil microorganism surveys at cadaver sites and paired controls during the summers subsequent to cadaver deployment. We expect I) that arctic foxes will be the main terrestrial mammalian scavengers, II) that the scavenger community is spatially structured, with polar bear scavenging being relatively common along the coastline but virtually absent inland, and iii) that cadavers used by polar bears have a relatively low local impact on soil microorganisms and vegetation. The process of spatially structured resource consumption by scavengers may contribute to creating spatial heterogeneity in tundra ecosystems.

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Poster 4

Red foxes in the Canadian High Arctic: competition with the Arctic fox and winter movements

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Rapid range expansion of boreal forest predators onto the tundra may disrupt local ecological processes, notably through competition with ecologically similar species. Red foxes have expanded their range northwards throughout the Canadian Arctic, inducing competition with endemic Arctic foxes. We studied competition between Arctic and red foxes, with a focus on interference competition, and winter movements of red foxes using satellite telemetry and den occupancy data from both species. We worked at Bylot Island (Nunavut) and Herschel Island (northern Yukon), two sites at the northern limit of the red fox's range. As expected, red fox home ranges were 56% larger on average than Arctic fox home ranges. However, red foxes did not exclude Arctic foxes regionally nor did they prevent them from breeding successfully in their vicinity. On Bylot Island, Arctic foxes did not spatially avoid red foxes more than their conspecifics, as evidenced by similar intra– and interspecific home–range overlaps. On Herschel Island, the red fox pair's home range extensively overlapped the home range of their Arctic fox neighbors. While red foxes tracked on Bylot Island survived several winters without expanding or leaving their home ranges, those on Herschel Island moved onto the sea ice and died. Overall, our results demonstrate low levels of interference competition between the two species in the Canadian High Arctic. When red fox density is low, as in our study areas where land protection prevents predator subsidization by anthropogenic food sources, Arctic and red foxes may be able to co–exist with limited antagonistic interactions. Our sample sizes were limited by the naturally low density of red foxes at their northernmost edge. Replication therefore is needed to fully understand winter space use and intraguild interactions in this species at its northern range limit.

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Poster 5

Assessing predation risk of arctic fox and other terrestrial predators on sandpiper (Calidris spp) nests in the arctic tundra

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The arctic fox (*Vulpes lagopus*) is recognized as the main terrestrial predator on most tundra's ecosystems. It relies on small rodents such as lemmings as primary preys, and switches to alternative preys (i.e. geese or carrion) when the primary prey is scarce. Through changes in behaviour and demography of the arctic fox (i.e. increased level of foraging activity, change in spatial use) this shift between primary and alternative prey can also alter predation pressure on incidental (or "accidental") preys, such as *Calidris* nests, opportunistically eaten when encountered.

Since predation by arctic fox is supposed to be the main driver of *Calidris* nests failure in the arctic, the estimation of its rate has received a lot of attention. However, it is often difficult and time consuming to find and monitor natural nests, which usually results in analysing only small sample sizes. Other protocols have thus been proposed to estimate predation risk, e.g. artificial nests or observational data of predators. Our goal is to assess whether these two protocols are efficient to estimate trends of predation risk on *Calidris* nests across years that are characterized by varying abundance of alternative and primary prey of the arctic fox. Using artificial nests (including "covered" ones, supposed to be only predated by foxes) and observational data (of arctic foxes and other predators like skuas, gull, raven, etc), we tested whether *Calidris* nests failure rate was better explained by artificial nests or observational data with capture recapture analysis. Our data also allowed us to test if nest survival is actually more related to index of fox predation risk than other predators, as often believed in the literature. Here we present the first results of this joint initiative and its future challenges.

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3.4 Session IV – Movement and spatial ecology

Poster 6

Revisiting Arctic fox movement modelling with optimal transport and machine learning

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Developing rigourous ecological models is fundamental to understand and predict how ecosystems may change across spatial and temporal gradients. In particular, realistic modelling of movements of the Arctic fox, one of the main predators of the circumpolar tundra, holds great promise to further our understanding of how the landscape of fear influences prey distribution in a dynamic Arctic. The use of spatial simulation methods to answer relevant biological questions is however still in its infancy, and many open issues remain to be adressed. Notably, very few mathematically robust methods have been suggested to guarantee that an animal movement model responds to habitat features and environmental conditions in a way that is sufficiently similar to their real counterparts. In this regard, we propose a novel model selection and evaluation methodology that leverages recent theoretical and algorithmic advances in optimal transport, a field of applied mathematics seeking to develop geometric tools that are useful to compare probability distributions. We explain how we can reframe the goal of modelling the movement of an animal from GPS tracking data as a distribution matching one, and we show how our methodology can be used to evaluate the accuracy of various arctic fox movement models. Finally, we also show how we can apply our proposed metrics to investigate how machine learning algorithms can contribute to the understanding of Arctic fox decision making about movement and determine if they can improve the ability to reproduce patterns of higher–level of emergence compared to conventional statistical models.

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3.5 Session V – Physiology and genetics

Poster 7

Changes in environment cause dietary shifts in the Svalbard Arctic fox: A stable isotope study

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The Svalbard Arctic fox is a generalist top predator that link the terrestrial and marine ecosystems. Data series of carbon and nitrogen isotopes from muscle (winter) and fur (autumn) of Arctic foxes on Svalbard were analyzed to study dietary shifts of the foxes. Data of trapped foxes were available from the winter season 1997/1998 to 2019/2020. Data of the drastic increasing number of geese, number of reindeer carcasses, reducing sea ice extent and distance to the coast were assessed as potential drivers. The objectives were 1) investigate whether there are spatial and temporal trends in Arctic fox diet, 2) determine how important the changes in the environmental variables are for dietary shifts of the Arctic fox in different seasons and 3) determine whether other parameters like the distance to the coast and age class have any impact on the diet as inferred from stable isotopes. The results revealed a trend towards a more terrestrial diet for foxes on Nordenskiöld Land in both winter and autumn, a trend that seemed to be stronger in northern regions. The number of geese and the year–by–year fluctuations in number of reindeer carcasses had significant impact on carbon isotope values in winter, while sea ice extent did not reveal any significant effects. It was also found that dietary differences between coastal and inland foxes were highly significant, implying that the Svalbard foxes are more stationary than previously thought. Long time series of data were shown as valuable, signifying the importance of continued monitoring and sampling which improve models and give more accurate estimates.

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Poster 8

First results of chemical scent composition of supracaudal gland secretion of the arctic fox

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Like other animals, the Arctic fox uses chemical signals for social communication. Among other glands that produce chemical signals, the Arctic fox possess an elaborate glandular area on the dorsal surface of the tail, the supracaudal or tail gland. The tail gland of canids is a hepatoid glandular organ surrounded and penetrated by powerful hair erector muscles squeezing out its lipoprotein secretion onto the skin surface. The gland is most developed in solitary species (Arctic, Red, and Corsac foxes) where it is represented by powerful glandular layer with large secretion containers. It is less developed in species living in groups like jackals and mostly absent in domestic dogs. In Arctic foxes, the tail gland produces a sweet and pleasant smelling secretion that has been observed to increase shortly after social contact and may therefore provide an olfactory signal to other foxes. In contrast to other species there is no data on the chemical structure of supracaudal gland secretion of the Arctic fox so far. In an ongoing project we want to characterize the scent chemistry of the Arctic fox tail gland. This poster will present the first results on volatile chemicals that were analyzed by gas chromatography–mass spectrometry from hair of the tail gland from Arctic foxes in Greenland.

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Poster 9

Regional Differences in Tooth Wear of Arctic Foxes

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Accurate aging of carnivores is key to understanding population dynamics including individual life histories, reproduction and longevity. Cementum annuli analysis (CAA) and tooth wear are two popular methods for estimating age. Scoring tooth wear is minimally invasive and can prove more accurate for older individuals, especially when CAA results have a low reliability index due to pulp erosion. However, as noted by Chevallier et al. (2017), calibration of scores is required at the population level because of the potential influence of diet (and other factors) on tooth wear.

During a study of Arctic Foxes, *Vulpes lagopus*, on Shemya Island, Alaska, we noted what appeared to be excessive1 tooth wear. Shemya foxes subsist largely on intertidal invertebrates, including sea urchins, and beach–cast items (e.g., fish, birds). Consequently, Shemya foxes masticate coarse sand with most meals. To quantify Shemya fox tooth wear, we applied Chevallier et al. (2017)'s Teeth Condition Index (TCI) constructed from Arctic Foxes living on Bylot Island, Canada. Bylot foxes feed on lemmings, goslings and eggs found in the tundra, and marine mammals found on ice. Due to dietary differences, we predicted that Shemya foxes would exhibit faster rates of tooth wear per year of age, and higher levels of tooth wear overall, compared to Bylot foxes.

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3.6 Session VI – Management and conservation

Poster 10

Felles Fjellrev Nord II – Bringing back the Arctic fox in northernmost Fennoscandia

David BELL

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Twenty years ago, there were only 40–60 Arctic foxes left in Fennoscandia. Today there are more than 450 animals. Protection by law was not enough to bring the species back from the brink of extinction. Instead, massive conservation efforts were undertaken, and they continue until this day. The methods involve population monitoring, red fox culling, supplementary feeding, captive breeding, genetic research, and communication campaigns. Felles Fjellrev Nord II is the latest Arctic fox project to be co–funded by the European Union (Interreg Nord). Arctic foxes have become more numerous in many parts of their former distribution range in Fennoscandia, but in northernmost Norway, Sweden, and Finland the situation is still critical. In Felles Fjellrev Nord II, authorities and researchers in all three countries hope to make a difference by working together in the far north. To learn more about the project, please visit our conference poster.

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3.7 Session VIII – Diseases, parasites and pollution

Poster 11

Screening of vector–borne pathogens in Icelandic arctic foxes, *Vulpes lagopus*

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The current accelerated climate and landscape changes can influence the occurrence and spread of pathogens. This is especially true for vector–borne pathogens spreading towards the arctic habitats. During the last 30 years, average temperature has increased in Iceland, supporting more favorable conditions for ticks and other arthropod vectors. Accordingly, questing *Ixodes ricinus* ticks have been reported in Iceland, implying potentially new threats posed by tick–borne diseases both for animal (wildlife and domestic) and human populations. The aim of this study was to screen the arctic fox, the only native terrestrial mammal in Iceland, for vector–borne pathogens. Liver samples collected from 60 individuals in 2011–2012 were tested for vector–borne protozoan parasites (Trypanosomatidae, *Babesia*, *Theileria*, *Hepatozoon*) and bacteria (*Anaplasma*, *Bartonella*, *Borrelia*, *Ehrlichia*, hemotropic *Mycoplasma*, *Rickettsia*) by PCRs targeting the 18S, 16S rRNA, msp2, *flagellin* and *glt*A genes, respectively. None of the pathogens were detected with the exception of an adult female fox from coastal ecotype being positive for *Anaplasma phagocytophilum*. Our results provide baseline evidence about the low prevalence of vector–borne pathogens in Icelandic arctic foxes; in light of the climate changes the geographic distribution of these pathogens might change, which require continuous monitoring in the arctic ecosystems, including both sedentary and migratory species.

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Poster 12

A Circumpolar Parasite: Genetic similarities between sucking lice collected from Arctic foxes, *Vulpes lagopus*, in Canada and Svalbard, Norway

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The circumpolar North has experienced unprecedented rates of warming over the past few decades, impacting the survival and development of insects and the pathogens that they carry. Recently, Arctic foxes from Canada (Nunavut) and Norway (Svalbard) were observed with fur loss over the neck and shoulders inconsistent with natural shedding of fur. Adult lice were collected from harvested foxes from both locations and were morphologically identified as sucking lice (suborder *Anoplura*). The only canine sucking louse that has been identified to date is *Linognathus setosus*, which is typically found on domestic dogs. Conventional PCR targeting the mitochondrial cytochrome c oxidase subunit 1 gene revealed that there were significant differences between *L. setosus* and the Arctic fox lice (87% homology), suggesting that Arctic foxes harbor a previously uncharacterized cryptic species of sucking lice. Furthermore, lice collected from Arctic foxes in Canada and Svalbard, Norway were 100% similar, indicating that there is gene flow between ectoparasites on Svalbard and North American Arctic fox populations. This further supports long distance dispersal of foxes from natal areas and verifies that long distance natal dispersal influences ectoparasite transmission across continents.

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Poster 13

Estimating Apicomplexan parasite exposure in Icelandic arctic foxes (*Vulpes lagopus*)

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The arctic fox (*Vulpes lagopus*) is the only native terrestrial mammal in Iceland. The population comprises both "coastal" and "inland" fox ecotypes, with regard to food resources. While coastal ecotype foxes mainly feed on sea birds and eggs, invertebrates and marine mammal carcasses, the inland foxes feed on ptarmigans, migrating waterfowl, eggs and wood mouse. Because of the relatively low biodiversity within arctic ecosystems and the involvement of the species in both marine and terrestrial ecosystems, Icelandic arctic fox population could serve as sentinels for overall ecosystem health of Iceland. It was demonstrated that coastal arctic foxes have higher levels of mercury, helminth burden and richness compared to the inland populations, indicating that the two ecotypes are quite separate and distinct. However, the presence of Apicomplexan parasites has not been reported in Icelandic foxes, yet. Using immunoblot analysis, we tested serum samples from 37 arctic foxes for the presence of antibodies to *Toxoplasma gondii*, *Neospora caninum* and *Besnoitia besnoiti*. A seroprevalence of 72.9% to *Toxoplasma gondii* antigens was found, whereas no antibodies were detected against the other two Apicomplexan parasites. There was no difference in exposure between gender and ecotype groups, however adult foxes had a significantly higher seroprevalence than juveniles (90.9% and 46.6%, respectively). Compared to previous studies from Svalbard, Canada and from Medny Island (51.7%, 40% and 5%, respectively), the seroprevalence in Icelandic arctic foxes is the highest. Since the seroprevalence in human population is low (10%), further studies on the ecology and epidemiology of *Toxoplasma gondii* in Iceland are warranted.

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Poster 14

Plastic in Arctic fox faeces of Iceland

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Plastic pollution is a growing concern in the Arctic and negatively impacts both marine and coastal organisms. Plastic has been identified in fulmars (*Fulmarus glacialis*) in Iceland. The Arctic fox (*Vulpes lagopus*) is the only native terrestrial mammal species in Iceland and is known to prey upon fulmars. The aim of this study was to investigate the potential for using Arctic fox faeces as a monitoring tool for plastic pollution in the Arctic environment.

Arctic fox faeces were collected in different regions of Iceland and analysed for both plastic presence and diet composition. In total, 235 faecal samples from 1999, 2017, 2018 and 2020 were analysed. The overall frequency of occurrence of plastic and other anthropogenic material was 5.11% and was found in samples from all regions and years. There were no statistical differences in plastic ingested, depending on year, region or methodology. There were no obvious differences in diet composition between samples that contained plastic and samples without plastic. No clear evidence for trophic transfer from fulmars to foxes was found. The suitability of Arctic fox faeces as a monitoring tool remains debatable. Although the large distribution range of foxes and the non–invasive collection of sufficient sample sizes are basic requirements for a good monitoring tool, the overall low uptake of plastic, the unclear source of the plastic (marine or terrestrial) make the interpretation of the data difficult for monitoring of plastic litter in the Arctic. Nevertheless, the ingestion of plastic in Arctic foxes remains a concern and warrants further studies.

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Poster 15

Occurrence of ingested human litter in winter arctic foxes (*Vulpes lagopus*) from Svalbard, Norway.

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The aim of this study is to assess the occurrence of human litter ingested by arctic foxes (*Vulpes lagopus*) caught in Svalbard, Norway, in winter when scavenging is at its highest. Twenty arctic fox stomachs and intestines were examined for human litter and plastic using the protocol from the Oslo–Paris Convention (OSPAR) for monitoring plastic ingestion by the northern fulmar (*Fulmarus glacialis*) (human litter and plastic > 1 mm).

The arctic foxes had ingested human litter at a low frequency (15%, 3 out of 20 foxes). One had 7 pieces of 3 mm thick cotton rope in the stomach (0.7 g, female, age 1 year), the second had one small, 1 by 1 cm, piece of wool (0.006 g, only stomach, male, age 1 year), and the last had ingested parts of a Belarusian cream carton (both stomach (19 pieces, 0.7 g) and intestine (6 pieces, 0.03 g), female, age 1 year). The carton was labelled with #84 C/PAP (Figure 2), which is made of paper/cardboard, plastic and aluminium sandwiched together. None of the plastic from the carton had fragmented off into the stomach and intestine.

Despite the low sample size, we do not regard ingestion of human litter as an immediate threat to the arctic fox population in Svalbard.

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Poster 16

Does claw predict mercury concentration in other tissues of red foxes?

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Mercury is a ubiquitous trace element that organisms mainly take up through ingestion. Mercury bioaccumulates in organisms, and biomagnifies through aquatic food webs from lower to top trophic levels, causing adverse biological effects above certain concentration thresholds. Environmental monitoring of mercury has primarily focused on aquatic organisms (e.g., fish, marine mammals, and waterfowl). Here we report a study on mercury concentrations in the red fox which could be a good sentinel species for monitoring mercury in the less–studied terrestrial food webs, due to its high trophic position and higher densities than larger terrestrial carnivores. We quantified total mercury concentration (THg) in tissues of red foxes near Arctic tree line in Canada collected from fur trappers in winter. Hair offers a non–invasive way to assess mercury exposure in diverse species, but variable and poorly understood molt patterns in wildlife often hamper the interpretation of tracer levels in hair. We assessed if THg in red fox claws could be used instead of hair to predict THg in several internal organs because claws grow continuously, and growth rate may be easier to monitor than molt patterns. Like other studies, we found strong relationships between the THg of diverse internal organs, but both THg in claws and hair were poor predictors of THg in internal organs. Because foxes are often nomadic in winter, their mercury exposure likely varies over the course of winters, which translates into a weak match of THg concentrations between active and inactive tissues. During reproduction and young–rearing periods, foxes are constrained to foraging near dens, which would likely result in a more constant exposure to mercury, and therefore THg in claws may better predict THg internal organs within the breeding season. Our results warrant further investigation of the co–variation between THg in internal organs and inactive keratinaceous tissues.

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Poster 17

Variation in feeding habits and food availability have minor influence on temporal trends of pollutants in arctic foxes from Svalbard

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The aim of this study was to investigate whether temporal trends of pollutants in Arctic foxes are influenced by climate–related variation in feeding habits and food availability. Samples were collected from 109–209 young (1–2 year–old) foxes trapped in Nordenskiöld Land, Svalbard, during the annual harvest (November–March) 1997–2019. Liver samples were analyzed for polychlorinated biphenyls (PCBs), organochlorine pesticides (OCPs), polybrominated diphenyl ethers (PBDEs), perfluoroalkyl substances (PFASs) and total mercury. Feeding habits were studied using stable isotope values in muscle tissue. The number of reindeer carcasses observed during the summer preceding the trapping season and sea ice cover during trapping season were used as proxies for reindeer and seal, respectively, as available food items. Foxes feeding on marine and higher trophic level food items showed higher concentrations of all studied compounds. Concentrations of some compounds increased the more sea ice was available and decreased with increasing reindeer mortality. Measured concentrations of the legacy pollutants (PCBs, PBDEs and most OCPs, perfluorooctane sulfonate) decreased over time. Trends of the above–mentioned compounds that were adjusted for variation in feeding habits or food availability, were generally similar to the measured trends. Measured concentration of some of the PFASs (long chain perfluoroalkyl carboxylates) showed a non–linear increasing trend, whereas the adjusted trends increased linearly. Temporal increase in Hg levels was slightly faster when the concentrations were adjusted for variation in diet and food availability. In conclusion, temporal trends of pollutants in Arctic foxes in Svalbard are mainly affected by emissions but year–to–year variability was linked to climate–related variation in feeding habits and food availability.

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